SUSTAINABLE BUILDING PRACTICES

- Minimising the Life-Cycle Environmental Impact of High-Rise Apartments in Korea -

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DECLARATION

I declare that this thesis has been composed entirely by myself and is wholly my own original work

Samuel Kim

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To God my lord, who empowered me whenever I felt discouraged.

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ABSTRACT

Concern about the global environment has been increasing in recent years. Efforts to sustain the globe as well as human beings have increased, especially in the late twentieth century. Co-operation between industries is required, in order to limit our production and waste within global capacity.

This current study researches one of the solutions which can contribute to sustaining the world environment. Although the issues are on a global scale, solutions are sought on a regional scale, in this case Korea. Assessment and proposals are made for high-rise apartments, one of the most popular construction types nowadays in Korea. Since the volume of high-rise apartment construction is so great, a small improvement in each building will make a great contribution to reducing environmental impact.

Assessments are made over the life-span of apartment buildings by using a tool for Environmental Impact Assessment for High-rise Apartment (EIAHA), whose components include passive design strategies; construction and building materials; energy consumption during building operation; and management and maintenance. The assessment is applied to the current high-rise apartment development in Korea as well as in the United Kingdom, Hong Kong and Singapore. Through the comparison of the development in those countries, proposals for future Korean high-rise apartment development are suggested.

Solutions for sustainable future development of Korean high-rise apartments are categorised into (i) energy saving strategies, which include energy use for construction and use of materials as well as energy in use, and (ii) strategies for a longer-life building. At the end of this study, as a conclusion, implications for planners, architects, legislators, managers and residents are outlined, in order to meet the targets established.

TABLE OF CONTENTS

Declaration	ii
Acknowledgements	iii
Abstract	iv
List of Table	xi
List of Figure	xiii
INTRODUCTION	1
1. Problems	1
2. The Purpose and Scope of the Thesis	3
3. Framework of the Thesis	4
Chapter 1. INTERACTIONS BETWEEN GLOBAL ENVIRONMENT ISSUES AND BUILDINGS	8
1-1. Issues of Sustainable Development	9
1-1-1. Global Environmental Change	9
1-1-2. Sustainable Development	17
1-2. Political Efforts for protecting the Global Environment	19
1-2-1. Basic Concept of the Environmental Policy	19
1-2-2. Development of International Environmental Policy	22
1-2-3. Negotiations on Global Environmental Issues	25
1-2-4. Conflict against the Development of International Environmental Policy	29
1-3. Environmental Issues and Buildings	31
1-3-1. Environmental Impacts of Buildings and the Construction Industry	31
1-3-2. Green Architecture Issues	35
1-3-3. The Life-cycle Approach for Sustainable Architecture	40
Summary of the Chapter	41

Chapter 2. ENVIRONMENTAL MOVEMENT AND POLICY IN KOREA 48
2-1. General Overview of Korea 49
2-1-1. Natural Environment 49
2-1-2. Population Trends and Cities 55
2-1-3. Economic Growth and Welfare 57
2-2. Environmental Conditions and Movements 58
2-2-1. The State of the Environment 58
2-2-2. Energy and the Environment 66
2-2-3. Public Awareness and Citizen Participation in Environmental Issues 71
2-3. Environmental Regulation and Policy 74
2-3-1. Governmental Organisation 74
2-3-2. Environmental Policy 76
2-3-3. Co-operation with Global Environmental Protection 78
Summary of the Chapter 81

Chapter 3. HOUSING AND HIGH-RISE APARTMENTS IN KOREA 85
3-1. Characteristics of Residential Buildings 86
3-1-1. Housing and Dwelling 86
3-1-2. High-Rise Residential Buildings 88
3-1-3. Terminology for Residential Buildings in Korean Context 89
3-2. Regulations related to High-rise Apartment Development 91
3-2-1. Social and Economic Elements for Apartments 91
3-2-2. Architecture Regulations 93
3-2-3. Environmental Policy Applied to Apartments 96
3-3. History of Apartment Development with the reference to Social Changes 98
3-3-1. Commencing Stage of Apartment Construction in the 1960s 98
3-3-2. Appearance of High-rise Apartments and Massive Construction in the 1970s 100

3-3-3. New Generation of Apartment Construction from the 1980s 102

3-3-4. Summary of Apartment Construction History 104

3-4. New Town development and Apartment Construction 108

3-4-1. The Five New Town Development Plan 108

3-4-2. Pundang New Town 110

3-4-3. Apartment Construction in Pundang 114

3-5. Problems of Current High-rise Apartment Development 118

3-5-1. Quantity or Quality 118

3-5-2. Construction Accidents in the 1990s 121

3-5-3. High-rise Apartment Estate 121

Summary of the Chapter 122

Chapter 4. A TOOL FOR ENVIRONMENTAL IMPACT ASSESSMENT FOR HIGH-RISE APARTMENTS (EIAHA) 127

4-1. Introduction of the EIAHA 128

4-1-1. The Need for an Environmental Impact Assessment of Korean High-rise Apartment 128

4-1-2. Analysis of Current Environment/Energy Assessment Tools 130

4-1-3. Development of the EIAHA 139

4-2. Passive Design Element 143

4-2-1. Climate and Comfort 143

4-2-2. Passive Solar Design 145

4-2-3. Thermal Insulation and Ventilation 146

4-3. The Issue of Building Materials 148

4-3-1. Environmental Impact of Materials 148

4-3-2. The Embodied Energy of Building Materials 157

4-4. Energy Use during Building Occupancy 165

4-4-1. Heating Installation 165

4-4-2. Central Heating and District Heating 167

4-4-3. Underfloor Heating 172

4-5. Long Term Analysis of Management and Maintenance 174
4-5-1. The Building Life 174
4-5-2. Maintenance Plan 176
4-6. Summary of the Credit Points of EIAHA 177
Summary of the Chapter 181

Chapter 5. APPLICATION OF EIAHA TO CURRENT KOREAN HIGH-RISE APARTMENTS 190
5-1. The Passive Design Element 191
5-1-1. Passive Solar Design 191
5-1-2. Thermal Insulation and Ventilation 193
5-1-3. Assessment of Passive Design 196
5-2. Building Materials 197
5-2-1. Construction Method and Use of Building Materials 197
5-2-2. Embodied Energy of Building Materials 202
5-2-3. Assessment of Building Materials 207
5-3. Energy Use during Building Occupancy for Thermal Performance 208
5-3-1. Energy Use for Thermal Comfort in Korean Apartment Buildings 208
5-3-2. Central Heating and District Heating 211
5-3-3. Underfloor Heating (Ondol) 215
5-3-4. Assessment of Heating System 217
5-4. Apartment Management and Maintenance 218
5-4-1. The Apartment Management System 218
5-4-2. Long-term Repair Plan and Fund for Special Repair 222
5-4-3. Life-cycle Energy Assessment of High-rise Apartments 225
5-4-4. Assessment of Building Life 226
5-5. Appraisal of Current Korean Apartment Development Assessment 228
Summary of the Chapter 229

Chapter 6. HIGH-RISE APARTMENT DEVELOPMENT IN OTHER COUNTRIES 236

6-1. British Development of High-rise Apartment Construction 237

6-1-1. High-rise Apartments in the United Kingdom 237

6-1-2. Efforts for Sustainable Development 241

6-1-3. Problems of Housing Development in the United Kingdom 246

6-2. High-rise Apartments in Hong Kong and Singapore 247

6-2-1. Characteristics of High-rise Apartments in Hong Kong and Singapore 247

6-2-2. Lessons of High-rise Apartment Development 251

6-2-3. Problems of High-rise Apartment Development 255

6-3. Comparison of High-rise Apartment Developments 256

6-3-1. Passive Design 256

6-3-2. Building Materials 259

6-3-3. Energy Use during the Building Operation for Thermal Control 261

6-3-4. Management and Maintenance 263

Summary of the Chapter 265

Chapter 7. PROPOSALS FOR FUTURE DEVELOPMENT OF KOREAN HIGH-RISE APARTMENT 271

7-1. Energy Saving Strategies of High-rise Apartment 272

7-1-1. Passive Heating Strategies for Improving Thermal Condition 273

7-1-2. Improving Mechanical Heating System for Energy Saving 275

7-1-3. Energy Saving through Building Materials 278

7-1-4. Policies for Energy Saving 279

7-2. Life Cycle Planning of High-rise Apartment 281

7-2-1. Design with Life-cycle Impact on the Environment 281

7-2-2. Management and Maintenance System of High-rise Apartment group 283

7-2-3. Social Recognition of Long-life Building 284

Summary of the Chapter 285

CONCLUSION 288

1. Summary of the Thesis 288

2. Implications for Related People 291

3. Limitation of Current Research and Further Suggestions 293

Bibliography 296

Appendix 1. Masterplan of Pundang New Town in Korea 315

Appendix 2. Number of Apartments in Pundang 316

Appendix 3. Location of Apartment Estates in Pundang 321

Appendix 4. Pictures of Apartments in Pundang 322

Appendix 5. Site-plan and Unit-plan of Five Apartment Estates 330

Appendix 6. Pictures of High-rise Apartments in the United Kingdom 343

Appendix 7. Pictures of High-rise Apartments in Hong Kong 350

Appendix 8. Pictures of High-rise Apartments in Singapore 354

LIST OF TABLE

Table 1-1	Greenhouse Gases and Their Main Sources	12
Table 1-2	Ozone Depleting Substances	14
Table 1-3	A Chronology of the Politics of the Ozone Layer Depletion	27
Table 1-4	A Chronology of the Politics of Climate Change	28
Table 2-1	National Environmental Standard for Air	60
Table 2-2	Air Pollution Levels of Major Cities (1994)	64
Table 2-3	Trends of Energy Consumption in Korea	69
Table 2-4	International Environmental Conventions which Korea has Joined	79
Table 3-1	Masterplan of Five New Towns around Seoul	109
Table 3-2	Land Use Plan - Pundang	113
Table 3-3	Details of Selected Apartment Estates in Pundang	117
Table 3-4	Number of Housing Unit by Types in 1990 and 1995	119
Table 4-1	Global Issues and Use of Resources in Environmental Standard Award and the Homes for a Greener World Competition	135
Table 4-2	Elements of EIAHA (Environmental Impact Assessment of High-rise Apartment)	142
Table 4-3	Embodied Energy and CO_2 Production of Concrete	159
Table 4-4	Embodied Energy and CO_2 Production of Steel	160
Table 4-5	Embodied Energy and CO_2 Production of Brick	161
Table 4-6	Embodied Energy and CO_2 Production of Timber	162
Table 4-7	Embodied Energy and CO_2 Production of Insulation	163
Table 4-8	Embodied Energy and CO_2 Production of Glass	164
Table 4-9	Indicative Embodied Energy and CO_2 Production of Chosen Building Materials	165
Table 4-10	Credit Points of the EIAHA	178
Table 5-1	Regulation of K-value in Buildings in Korea	193
Table 5-2	Regulation of Thickness of Insulation	194
Table 5-3	Summary of Credit Points for Passive Design	196

Table 5-4	Construction Cost in an Apartment Building	199
Table 5-5	Materials Used in an Apartment Building	200
Table 5-6	Embodied Energy of Materials Used in an Apartment Building	203
Table 5-7	CO_2 Production of Materials Used in an Apartment Building	205
Table 5-8	Embodied Energy and CO_2 Emission for constructing an Apartment Building and Apartment Construction in the Entire Pundang New Town	206
Table 5-9	Summary of Credit Points for Building Materials	207
Table 5-10	Regulation on Structure and Material of Underground Heating	216
Table 5-11	Summary of Credit Points for Heating System	217
Table 5-12	Monthly Management Fee in Hanyang Estate in Pundang	221
Table 5-13	Recommended Duration for Repair Plan of Ministry of Construction (MoC) and Korea National Housing Cooperation (KNHC)	224
Table 5-14	Energy Use of Apartment Buildings for the Life of 25 Years and 50 Years	226
Table 5-15	Summary of Credit Points for Building Life	227
Table 5-16	Summary of Credit Points and Grade of Current Korean High-rise Apartment Development by EIAHA	228
Table 6-1	U-values of Dwelling Buildings in 1990 and 1995 (England and Wales)	242
Table 6-2	Preferable Building Component in Terns of Embodied Energy	244
Table 6-3	The Environmental Standard Award for New Homes in the United Kingdom	245
Table 6-4	Comparison of Passive Design	258
Table 6-5	Comparison of Building Materials	260
Table 6-6	Comparison of Heating or Cooling Systems	262
Table 6-7	Comparison of Management and Maintenance	264

LIST OF FIGURE

Figure 1-1	Existent Greenhouse Gases by Percentage	11
Figure 1-2	United Kingdom Delivered Energy Consumption by Sector and by Delivered Fuel Type (1987)	32
Figure 1-3	United Kingdom Carbon Dioxide Emission by Sector and by Delivered Fuel Type (1987)	33
Figure 2-1	Annual Mean Temperature Chart in Korea	50
Figure 2-2	Mean Monthly Temperature by the Region	51
Figure 2-3	Mean, Average Maximum and Average Minimum Temperature in Seoul in 1992	52
Figure 2-4	Average Relative Humidity, Sunshine Ratio and Sunshine Hours per Day by Month in Seoul between 1990 and 1994	53
Figure 2-5	Trends of Mean Temperature in Urban and Rural Area	54
Figure 2-6	Percentage of Total Korean Populations in Seoul and Capital Region	56
Figure 2-7	Trends of GNP per Person	57
Figure 2-8	Trends of Yearly Average Sulphur Dioxides in Major Cities	61
Figure 2-9	Trends of TSP in Major Cities	62
Figure 2-10	Trends of Acid Rain in Major Cities	63
Figure 2-11	Trends of General Waste Produced per Year	66
Figure 2-12	Trends of Energy Use	67
Figure 2-13	Trends of Oil Consumption in Korea and the United Kingdom	68
Figure 2-14	Yearly Environmental New Items in National Newspapers	72
Figure 3-1	Housing Types in the Korean Context	90
Figure 3-2	Trends of Family and Housing Numbers	104
Figure 3-3	Trends of Average Family Size	105
Figure 3-4	Trends of the Number of Housing Units Constructed	106
Figure 3-5	Trends of Housing Spread Rate	107
Figure 3-6	Location of the Five New Towns around Seoul	108
Figure 3-7	Development Steps of Pundang New Town	111

Figure 3-8	Community Zone in Pundang	112
Figure 3-9	Plot Ratio of Apartment Estates in Pundang	119
Figure 5-1	Components of Walls, Roofs, Floors and Windows in Apartment Buildings built by KNHC	195
Figure 5-2	Embodied Energy of Materials in an Apartment Building	204
Figure 5-3	CO_2 Production of Materials in an Apartment Building	206
Figure 5-4	Heating, Hot Water and Electricity Bill by the Month between October 1993 and October 1994 - in the Case of Hanyang Estate in Pundang	209
Figure 5-5	Energy Used for Heating, Hot Water and Electricity by the Month between October 1993 and September 1994 in Han yang Estate	210
Figure 5-6	Energy for Heating and Hot Water by the Months in 1991 - in the Case of an Apartment Estate in Seoul	211
Figure 5-7	Comparison of Air Pollutants Between Central and District Heating Mode	213
Figure 5-8	Comparison of Energy Use for Heating and Hot Water between Central Heating and District Heating Systems - in the Case of an Apartment Estate in Seoul	214
Figure 6-1	Age of High-rise Apartment Buildings in the United Kingdom in 1988	239
Figure 6-2	Embodied Energy and Energy-in-use over a 25 year Life	240
Figure 6-3	Embodied Energy and Carbon Dioxide Emission of Insulation	243
Figure 6-4	Summary of Comparison of High-rise Apartment developments	266

Introduction

1. Problems

The world is now facing a global crisis that threatens the survival of ecological systems, including the human race. World societies have industrialised faster and faster in this century, causing the globe to change much more quickly than ever before, thus provoking and aggravating problems. Among these problems, environmental damage is particularly severe. In pre-industrial societies, sustainability was inherent, since production and consumption stayed within their natural boundaries, in harmony with the environment. Since the rapid change of societies through industrialisation, however, the delicate balance between human beings and their environment has been destroyed. There are many examples of environmental disorders including the exhaustion of finite natural resources such as fossil fuels, minerals, and metals; the over-exploitation of renewable resources such as forests and agricultural land; the loss of biodiversity through the extinction of plant and animal species; and pollution crises such as acid precipitation, soil oxidation and erosion, toxic contamination of food supplies, ozone depletion, and climate change.[1]

The environment is not only an important issue due to the gravity of the damage done, but also because of the sheer scale of the problem; it is a world-wide concern. Issues such as global warming, ozone layer depletion, acid rain and deforestation can not be solved by one society or state alone. Indeed the last few decades have seen many international efforts, such as conferences, organisations and events, aimed at solving global environmental problems. These have led to the creation of a multitude of international treaties and protocols, from which each nation has drawn up policies in an attempt to save or improve their national and regional environment, as well as the global environment. However, these treaties have tended to work as barriers to industries and trades throughout the world.

The construction industry, as one of those sectors affected by these treaties and protocols, is now forced to find ways of achieving a sustainable future. Buildings themselves cause many environmental problems, starting from their initial construction right through to their final disposal. Large amounts of raw materials are used in construction and waste is continually produced from buildings during their life-cycle. Some materials used in the construction industry are a threat to human health, and simultaneously endanger other species. A massive proportion of energy consumption is related to buildings in their construction process, operation and maintenance, or demolition. Land, water and air are polluted by buildings or the by-products of buildings: air pollutants, for example, are mainly formed by the operation of heating and cooling facilities.

Current trends in environmental concern have, and will continue to play, a major role in the building and construction industries. To adhere to effective environmental policies and treaties for buildings, designers, as well as policy makers and town planners, need to thoroughly understand the building process and the relationship between buildings and the environment. The interactions between buildings and the environment are various. On the global level, the impact of buildings on world atmospheric pollution manifests itself through the greenhouse effect, acid rain and ozone depletion. Buildings are responsible for the depletion of resources, through the use of raw materials and energy. Besides the global scale, buildings have an impact on the local outdoor and indoor environment, for instance, builders have a responsibility toward local ecology, including issues such as the variety or rarity of wildlife in an area. Furthermore, a building may affect the health, comfort and safety of occupants through the effects of, for example, indoor pollution. The highest concentrations of most airborne pollutants are found indoors where, on average, the adult population of Europe and America spends 90 per cent of its time.[2]

There have been efforts to assess the impact of buildings on the environment, especially in western countries.[3] However, efforts for housing construction in developing countries have concentrated upon solving housing crises through producing a massive amount of housing units. In order to fight against global environmental degradation as well as to solve national and regional housing problems, solutions for a sustainable development in housing construction should take local social, cultural and political situations into consideration. Housing development in South Korea is as unique as that of any other country, requiring its own solutions for a sustainable future development.

2. The Purpose and Scope of the Thesis

Environmental situations vary according to each country, being connected with national political, social and economic conditions. Consequently, the answers for sustainable development for housing construction will be different in each country. The purpose of this thesis is to explore frameworks for sustainable development for Korean housing. Since most of the recent housing developments are in the form of high-rise apartments, solutions are sought for such developments. The term 'Korea' used throughout this thesis refers only to 'South Korea'.

As mentioned, the environmental impact of buildings is manifold. Whilst there is ample research focusing on regional impacts or on indoor environmental factors such as indoor air pollution and soundproofing (noise insulation), there is little evidence of concern about the global environment from the Korean construction industry. In this thesis, an assessment of the impact of apartment buildings on the environment will focus on the global perspective with a brief mention of the regional or indoor environment, although the significance of the latter is acknowledged. The relationship between buildings and the environment will be focused upon an analysis of the impact of policy on buildings and building construction. The assessment of, and proposals for, Korean high-rise apartments is mostly related to energy consumption, use of building materials and waste production, throughout the life-cycle of the building. Ways of prolonging the life of a building are also investigated, since a longer life could mean saving on materials and energy which would otherwise be used in the reconstruction of an old building. Assessments are divided into passive design strategies, selection of building materials, heating systems and building maintenance, followed by a summary guide to the regulations for each item.

In order to draw an effective conclusion, proposals for new apartment developments in Korea are described, with some references to appropriate models in other countries, namely the United Kingdom, Hong Kong and Singapore. The proposals then focus on energy-saving strategies and life-cycle design. After summarising the thesis, implications for people who are involved in high-rise apartment development are outlined in the conclusion, followed by proposals for future research.

3. Framework of the Thesis

The thesis consists of seven chapters.

The first chapter examines the global environmental issues of modern society. During the transition from primitive to industrialised societies, global environmental conditions have reached a crisis, though human living standards have improved at least in a materialistic sense. People are making greater efforts to protect the environment, as the seriousness of the problems has deepened. Political efforts in finding solutions for these global environmental issues have risen, thanks to scientific evidence of environmental damage. After considering political efforts to solve the global crisis, the relationship between global environmental issues and buildings is described. Attempts to achieve a sustainable society in the building and construction industries are shown as ideas establishing sustainable architecture for high-rise apartment construction.

Chapter Two looks at the environmental situation and policies in a specific country, that is Korea. It also gives a general overview of Korea, in relation to its construction industry. As a country with one of the fastest growing economies in the world, the environmental conditions in Korea have taken priority over other issues. As people have become increasingly anxious about the condition of the environment in Korea, visible improvements have been made. However, in order to develop a sustainable society, more attention to the environment is required. Cooperation on global environmental efforts is especially important, since policies for the global environment are not yet well established.

Chapter Three begins by exploring the origin and history of Korean high-rise apartments dating from the late 1950s. High-rise apartments are one of the most popular construction types in Korea, and are seen as an appropriate building type for study. Trends in apartment construction are investigated with references to social, economic and political changes. Discussion of general problems in recent apartment construction is followed by the example of a current apartment construction, which is an essential part of new town developments around the Seoul metropolitan area. Since there is still a massive demand for new housing in a relatively short time, trends in high-rise apartment construction will continue for a while, making it necessary to assess the impact on the environment.

Chapter Four establishes a tool for the assessment named EIAHA (Environmental Impact Assessment for High-rise Apartment). At the beginning of the chapter, the EIAHA is developed for high-rise apartment construction by looking at the life-cycle of buildings, with references to material and methodologies developed by BRE, BSRIA and others. The key factors include passive design elements for improving thermal comfort; the wise use of building materials; proper installation for heating facilities; management and maintenance programmes for extending building life. All of those factors have the potential to minimise the environmental impact from building industry.

The application of EIAHA to current Korean high-rise apartments is demonstrated in Chapter Five. Korean high-rise apartments are assessed item by item throughout this chapter. Through this assessment, good strategies which should be encouraged for sustainable development will be pointed out, as well as the requirement of careful inspection of bad design.

In Chapter Six, examples of high-rise apartment developments in the United Kingdom, Hong Kong and Singapore are described for its purposes of comparison. In the United Kingdom, which was a pioneer of high-rise apartment development, the reputation of high-rise apartments has worsened in recent decades. The lessons from this failure are outlined for the benefit of future development in other countries. Hong Kong and Singapore are two of a few countries that have successful development in high-rise apartments. Through their achievements, it has been recognised that high-rise apartments can be 'real home' for people. Hong Kong and Singapore are chosen as exemplary models for future high-rise development in Korea. A comparison of high-rise apartment development in these countries is made at the end of this chapter, in order to help to establish a proposal for future Korean development.

Chapter Seven advances proposals for reducing the environmental impact of Korean high-rise apartment development. The proposals are made in two major categories; energy-saving strategies and life-cycle planning. Although these are divided into two main topics, items in each part are interrelated with each other. A short conclusion of the whole thesis is made after this chapter, and a summary of the thesis is shown, including the implications for key personnel who are involved in Korean high-rise apartment development.

Notes and References

1 Roger Talbot, *Architecture for a Sustainable Future; Propositions, Paradoxes, Principles and Practice*, Lecture to the Architectural Institute of Korea, July 1994, p1.

2 Josephine J. Prior, *Environmental Standard - Homes for a greener world*, Building Research Establishment Report, 1995, p1.

3 The Building Research Establishment (BRE) has produced a series on research on the environmental impact of buildings by building sectors. The list below is these separate reports which are shown by building sectors.

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C. R. T. Lindsay, P. B. Bartlett. A. Bagged, M. P Attenborough and J. V. Doggart, *An environmental assessment for new industrial, warehousing and non-food retail units*, BREEAM/New Industrial Units. Version 5/93, BRE Report, 1993.

Chapter 1

Interactions between Global Environmental Issues and Buildings

This chapter, as an opening chapter of the thesis, looks at environmental issues in the past, now and in the future. Natural environmental conditions have changed because of man-made environments. People have recognised that without any efforts to protect the environment, human beings, as well as all other living species, cannot survive. Hence, people are trying to solve the current environmental problems. The first part of this chapter aims to give a concise description of current global environmental problems, such as global warming and ozone depletion. It continues to describe the idea of sustainable development which maintains the quality of human life and harmony with nature.

Although the recognition of global environmental problems is the first step to solving them, increased knowledge will not improve the situation unless it is associated with social and political efforts.[1] During the second half of this century, especially since the early 1970s, attention has been given to intense international political efforts to try to solve the current environmental problems, with many international organisations, events and conferences. The second part of this chapter will look at the political efforts being made to solve global environmental problems.

Buildings, as shelters, were originally for people to escape from an unsound natural environment, but they began to produce pollutants during the building process and use of them. To make buildings, raw materials are used and consequently waste is generated. Some building fabric components have a harmful effect on the environment and human health. Following the raising of current environmental issues, there have been some efforts to reduce the number of environmentally degrading elements from buildings. The last part of this chapter investigates the impact of the construction industry on the environment, and the reaction of architects to the current environmental problems.

1-1. Issues of Sustainable Development

1-1-1. Global Environmental Change

Environmental problems are not a new concern. In terms of air pollution, as a dominant pollution problem, an example is found when early people discovered that a poorly ventilated cave is not the place to cook a meal. They may have managed to solve the problem with proper ventilation of the cave. However as society has grown, the improvement in a small place like a cave could not be an absolute solution, since many problems had expanded to towns, and then to cities. By medieval times, some local government agencies were empowered to investigate offensive sources of air pollution. In England, for example, four directives were given between 1285 and 1310 for companies to shift from wood to coal as the principal fuel in lime kilns.[2]

The environmental issues arising in this century are not only regional problems, but have also become global concerns. Growth in the world population and economy, increased and widespread industrialisation, and the development of society and international trade have occurred on such a scale that severe environmental damage and unsustainable exploitation of the Earth's resources are taking place on a global scale in the late twentieth century.

Rapid temperature change has proved to be the result of the accumulation of greenhouse gases such as carbon dioxide and nitrogen oxide. This phenomenon will increase sea levels which threatens some countries adjacent to the sea. The depletion of the ozone layer in the stratosphere by CFCs, man-made gases, crucially affects skin disease. Acid rain, water pollution, including rivers and oceans, and waste problems are also critical issues for the regional and global environment. Tropical forests are now being destroyed at an extraordinary rate which are crucial to climate change and loss of biological diversity. Oil and mineral resources are being consumed rapidly by industrialised and recently developing states, irreversibly depleting global reserves at a cost to underdeveloped states and future generations. Moreover, the dumping of waste-products into the air, sea and land has reached such a level that pollution has become a severe international and global problem.[3]

Global Warming and the Greenhouse Effect

One of the most dominant topics for the global environment in this century is global warming, which mainly occurs from the accumulation of greenhouse gases in the atmosphere. The greenhouse effect is a phenomenon that produces a higher temperature inside certain boundaries without having a heat source in itself. Once sunlight has passed through a window and is transformed into heat energy inside, the energy will not be radiated back outside. While short-wave solar radiation penetrates the glass and warms the surface below, long wave thermal radiation is absorbed by the glass, and some of this heat is kept inside, increasing the inside temperature.[4] A car left in the sun with the doors and windows closed can have much higher temperature inside than outside because of this phenomenon.

The greenhouse gases are the gases in our atmosphere which have a similar effect. The earth is covered with protective greenhouse gases in the lower atmosphere, or troposphere. These gases include carbon dioxide, methane, nitrous oxide, ozone and Chlorofluorocarbons (CFCs).[5] Without these greenhouse gases, the average global temperature would fall some 30°C,[6] which will threaten the survival of almost every living species. The problem in the modern world is that human activity is adding to the sources of greenhouse gases, making temperatures increase which will threaten the ecological system, including human beings. Carbon dioxide is proportionally the greatest of the gases causing global warming in our atmosphere, while CFCs have a thousand times the effectiveness of carbon dioxide. Greenhouse gases by percentage of the global warming effect are shown in Figure 1-1.

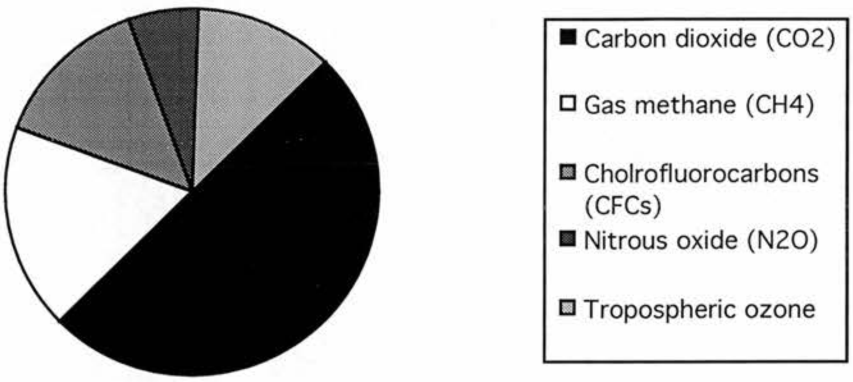

Figure1-1. Existant Greenhouse Gases by Percentage

Source : Brenda and Robert Vale, Green Architecture

Carbon dioxide makes the greatest contribution to the greenhouse effect. Reducing carbon dioxide accumulation is vital in acting against global warming, since the gas contributes to about half of the total global warming effect. One single molecule of carbon dioxide traps less heat than that of CFCs, but there are far more carbon dioxide molecules in the atmosphere than CFCs. There are 800,000 carbon dioxide molecules for every one CFC12 molecule.[7] About 80 percent of carbon dioxide accumulation to the atmosphere comes from the burning of fossil fuels, and the remaining 20 percent from the burning of forests and firewood and agricultural sources.[8] Burning fossil fuels is not only the cause of global warming, but also that of regional air pollution.

Methane is released to the atmosphere at the rate of about 525 million tons per year. The amount of methane in the atmosphere has been rising since the beginning of the nineteenth century, and there has been a more rapid increase of about 0.9% per year in the last few decades. A major natural source of nitrous oxide is that of living organisms on land and in the ocean. Atmospheric concentrations of nitrous oxide are increasing at a modest rate of about 0.25 % per year, probably due to human activity. While ozone is found mainly high in the atmosphere, there is also a notable amount in the lower atmosphere that acts as a greenhouse gas, namely tropospheric ozone. Tropospheric ozone occurs naturally but can be generated from emissions of primary pollutants such as oxides of nitrogen, methane, hydrocarbons and other compounds.[9] Greenhouse gases and their sources are described in Table 1-1.

Table 1-1. Greenhouse Gases and Their Main Sources

Greenhouse gas	Source
Carbon dioxide (CO_2)	Fossil-fuel burning Wood fuel Deforestation and land use change Cement Manufacture
Methane (CH_4)	Release from gas, oil or coal Production or transmission Enteric fermentation from ruminants (e.g. cattle, sheep, goats) Wetland rice cultivation Landfill waste sites Burning and decay of biomass
Chlorofluorocarbons (CFCs)	Used for solvents, refrigerants, aerosol spray propellants, foam packaging etc.
Nitrous oxide (N_2O)	Fertilisers Fossil-fuel burning Tropical deforestation and wildfires Land conversion for agriculture
Troposphere ozone	Generating from Nitrogen oxides (Fossil-fuel burning, Biomass burning) Carbon monoxide (Fossil-fuel burning, Biomass burning) Non-methane hydrocarbons (Evaporation of solvents and liquid fuels)

Source : Paul M, Smith and Kiki Warr, *Global Environmental Issues*, 1991, p174

Because of the greenhouse effect, the world temperature has been increased. The IPCC (International Panel of Climate Change) Working Group I predicted that there would be an increase in global mean temperature during the next century of about 0.3°C per decade if the world took no special action to limit emissions of greenhouse gases. This will result in a likely increase in mean global temperature of about 1°C above the present value by 2025 and 3°C above today's temperature before the end of the next century.[10] In that case, the sea level is predicted to rise 60 cm, which will threaten most countries adjacent to the sea. A combination of global warming and increased air pollution will lead to more disease. Smog could become more widespread as temperatures rise.[11] Accidental diseases such as dizziness are also connected with temperature increase, and a recent newspaper reported that the number of emergency calls (999) to Ambulance Services depends on temperature increase and air quality.[12] An increase in average global temperature would also shift climatic zones and unsettle ecosystems.

Depletion of the Ozone Layer

Ozone gas is vaguely blue in colour and has a pungent smell. It occurs throughout the atmosphere, but only in small amounts, never exceeding around one molecule in every 100,000. The ozone layer is found in the stratosphere, between 10 and 50 km above the ground. The ozone layer protects the earth from harmful ultraviolet radiation, shielding the earth from ultraviolet-C radiation and substantially reducing the amount of ultraviolet-B reaching the earth's surface. Ultraviolet-B can cause skin cancer and have harmful effects on plants and marine life. The increase in the concentration of man-made gases such as CFCs and HCFCs have led to a very significant depletion in the ozone layer during the second half of this century.[13] These compounds first came on stream in the 1930s, as ideal substitutes for noxious chemicals, because they are stable, non-flammable and non-toxic substances. They were then used as refrigerants. Because of the cheap production, the use soon expanded into other sectors such as propellants in aerosol sprays, blowing agents, solvents and cleaning fluids in many specialised areas.[14]

An early scientific breakthrough regarding the human impact on the ozone layer occurred in 1973, when two scientists at the University of California calculated that CFCs release chlorine, which has an immense ability to break apart ozone molecules, when CFCs are broken down by intense solar radiation at high altitudes.[15] CFCs pass very slowly up through the atmosphere into the ozone layer, where they break down to their basic constituents. A single atom of chlorine, one of these constituents, can help destroy 100,000 ozone molecules. Because of the slow process, it will take a few decades before the damage from CFCs' use is ended, even after the use of these substances has been stopped.[16] More recently it has been found that HCFC and Halon gas also have an effect such as CFCs have. The ozone depleting gases are shown in Table 1-2.

Table 1-2 Ozone Depleting Substances

Substances	Atmospheric Lifetime (years)	Ozone Depletion Potential	Current/Potential Applications
CFC 11	60	1.0	Foams, Aerosols, Refrigeration, Solvents, Air conditioning
CFC 12	120	1.0	Aerosols, Air Conditioning, Foams, Refrigeration
CFC 113	90	0.8	Aerosols, Foams, Solvents
CFC 114	200	1.0	Aerosols, Foams, Refrigeration, Air conditioning
CFC 115	400	0.6	Aerosols, Refrigeration
Halon 1301	110	10.0	Fire fighting
Halon 1211	25	3.0	Fire fighting
Halon 2402	28	6.0	Fire fighting
Carbon Tetrachloride	50	1.1	Feedstuff, Pesticides, Solvents, Pharmaceuticals
1,1,1 Trichloroethane (Methyl chloroform)	6.3	0.15	Solvents, Adhesives

Source : Department of the Environment, *The Ozone Layer*, London HMSO 1991, p6

Through the detection of a significant hole in the ozone layer above the Antarctic continent by the British Antarctic Survey, a major drop - up to over 30% - of the ozone level was discovered in the mid-1980s. Through new data collected by investigations continued after the middle of 1985, it was discovered that not only had global ozone depletion been far more severe than originally predicted, but an ozone crater could be forming over the Arctic as well. Evidence continued to be found in the 1990s. In the report of the WMO (World Meteorological Organisation) and UNEP (United Nations Environment Programme) in 1991, the level of ozone layer destruction was revealed to be greater than predicted, which has had a substantial impact upon most governments. In January 1992, researchers discovered ozone losses of up to 20 percent in the northern hemisphere, with a maximum depletion over Russia of 40-50 percent below normal for a few days. The British Meteorological Office noted that the lowest level of ozone ever recorded in either a February or a March had been uncovered in April 1993 and this trend continued through the rest of 1993.[17] The consensus of scientific opinion is that the problem of ozone layer depletion has not totally been solved. With emissions of ozone depleting substances continuing, many scientists are concerned that more action has to be taken.

Changes in the ozone layer would have significant consequences. As the ozone layer thinned, the incidence of skin cancer, cataracts and infectious diseases among humans would increase; agricultural yields of certain crops would decrease; many manufacturing materials would weaken prematurely; and ecosystems would be destabilised.[18]

Other Global Environmental Issues

Acid precipitation, marine pollution, depletion of biological diversity and desertification are also problems that have stretched to become global concerns.

Rainfall is normally slightly acidic, but where air is polluted with oxides of sulphur and nitrogen, precipitation produces strong sulphuric and nitric acids. Sulphur dioxide produced by burning coal and oil, and oxides of nitrogen produced by burning a wide range of fuels contribute to acid rain.[19] Acid rain inhibits plant nutrition and restricts the range of plant and animal life. Fresh water can become poisonous to plants, fish and other animals. Acid rain also damages buildings and damage from acid rain may occur hundreds of miles away from the source of acid pollutants.[20]

Marine pollution can be continuous or incidental. It can be deliberate or accidental. Pollutants vary in the time they remain in the ocean before being broken down into other substances, or being removed into sediments or to the atmosphere. Naturally-occurring substances, such as domestic sewage, usually persist for a short time in the ocean, but man-made substances, such as pesticides and toxic metal, persist for a longer time, having continuous and long-term effects on the ocean and being of most concern.[21] Pollutants enter the ocean by diverse routes. The main source is directly from the land, through outfall pipes into the ocean or from rivers, which can carry sewage, industrial waste, fertilisers and pesticides. Pollution also comes from the ocean, both accidentally and deliberately from ships and by the mining of ocean resources. Some pollutants reach the ocean by fall-out or wash-out from the atmosphere.[22]

Tropical rain forests are threatened by human activities for self-satisfaction. This area is vital for absorbing CO_2 which is the most crucial gas in global warming. The loss of tropical rain forests also affects biological diversity, the depletion of which is mainly because of the extension of human territory. The sequence of economic activities causes a further problem by producing massive amounts of unwanted waste, which can only be prevented through careful use and recycling of materials.

1-1-2. Sustainable Development

To avoid a crisis developing from the above problems, there have been many efforts on an international level. The sustainable development theory comes in this context. Among many definitions, the definition of sustainable development adopted by the Brundtland Commission is the most widely used, defining it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [23] This concept means looking ahead to the opportunities and constraints that will face us tomorrow, not merely those that face us today, and minimising the use of resources and thereby the consequent increase in global entropy.[24] Paul M. Smith and Kiki Warr emphasised four implications of the definition of sustainable development;

1) a concern about the relationship between resource use, population growth and technological development and advancement;

2) a concern about the production and the distribution of resources of food, energy and industry amongst the developed, developing and underdeveloped nations of the world;

3) a concern about uneven development, about the gross imbalances between the rich and poor nations, about economic dominance and ideological differences;

4) a concern about environmental degradation and ecological disaster.[25]

Although the idea of sustainable development concerns environmental degradation and ecological disaster, it is strongly human-centred. It is primarily concerned with maintaining human welfare through meeting human needs and ensuring the quality of human life. Sustainable development does not guarantee the needs or quality of life for animals or other living organisms, except where this will benefit humans. Some environmentalists argue that all living creatures have an inherent right to exist that is separate from their usefulness or value to humans.[26] But at least, concern for human beings can be the first step to maintaining the ecosystem.

Most economic activity, as an important modern human activity for sustaining human beings, uses up materials and resources and requires energy, which also uses up resources such as oil and coal. It also creates waste products which have to be disposed of on land, in the air or in the water, creating pollution. As economic activity grows and expands, the readily available materials and resources get used up and the environment deteriorates as a result of the pollution. Economic activities that are dependent on a healthy environment, such as agriculture, forestry, fishing, tourism and recreation, are directly affected if the environment is degraded. Other industries are indirectly affected as it becomes more expensive to obtain resources and because pollution decreases the health of the work-force. Sustainable development is therefore very much about ensuring that economic activity which supplies communities with food, shelter, manufactured goods and services can be continued into the future.[27]

However, sustainable development involves seemingly sound, common-sense adjustments to the way we do things. It does not mean a commitment to no real economic growth, rather it is a question of structural change of economic activities.[28] It accommodates itself to the existing national and international economic systems. It aims to make the necessary modifications that will enable our everyday business activities to be sustainable into the future. It is even argued that sustainable development opposed to those who believe that economic activities such as business-as usual, capitalist and free market economic systems are critical causes of environmental degradation.[29]

As the place of economic activity, cities have been a dominant cause of activity contra to global sustainability. Large city populations devour materials and food-stuffs, and consequently produce waste for their neighbours. Not only do they consume a lot of energy, but they discharge carbon dioxide and other toxic gases into the atmosphere. For example, London's direct energy consumption has reached some 20 million tonnes of oil equivalent per year, or two supertankers a week. London's carbon dioxide output, from the combustion of fossil fuels, is some 60 million tonnes per year. The critical point is that London could manage with half that energy consumption without changes in the standard of living, and could generate a very large number of jobs in the process.[30] By initiating a significant shift towards sustainable development, modern cities can become a major market for environmental technology through manufacturing plants for the production of recycling technology, CHP systems, photovoltaic cells, insulation, and a wide range of innovative building materials.[31]

The concept of sustainable development, however, is vague and subject to many and diverse interpretations. There are still profound differences in perspective between the richer and poorer societies of the world on issues of the environment and development. Nevertheless, the terminology has stimulated a reassessment of the meaning of development in an era full of environmental risks, in addition to becoming a bridge for efforts to set up a partnership between North and South for addressing the problems of environment and development.[32] The crucial point now is to harmonise human societies by changing their ethical points of view which will give pleasure in the conversion of their way of life, without the feeling of sacrifice.

1-2. Political Efforts for protecting the Global Environment

1-2-1. Basic Concept of Environmental Policy

Environmentalism is an alterating concept which includes complex and different social movements.[33] The definition of pollution as an environmental problem also depends upon public decisions concerning the proper use of the environment and the determination of tolerable levels of pollution. Environmental issues interact and interrelate with other development issues. Air quality issues, for example, link with health, energy, and economic problems. The common effect of science and policy analysis is to reveal environmental issues as more complex and comprehensive than as first perceived. Although scientists can define or describe the use of materials or the harmful effects of them, their thinking goes beyond scientific boundaries when they want to prescribe levels of use of what they have mentioned.[34] Technical prescriptions for a certain issue may be simple but found politically unfeasible. To implement technical solutions frequently requires a list of associated issues to be confronted.[35]

Any perceptive participant in the environmental debate very quickly realises that issues emerging on the environment constitute more than the question of how to solve those problems. There are underlying disagreements over how problems are defined, their degree of seriousness, who is responsible for solving them, and how amenable they are towards solution. These disagreements are based on different moral principles, different values, and different assumptions about how the world operates. Disagreements are found not only at the international level, where cultural diversity is to be expected, but also at all other levels, within a single society or organisation, and within the actions and policies of a single corporate group.[36]

To understand an environmental policy, the term policy itself should be defined. Oxford Advanced Learner's dictionary defines policy as " plan of action, statement of ideals, etc. proposed or adopted by government, political party, business etc." Lynton Keith Caldwell describes policy and environmental policy in the following ways:

> Policy does not necessarily imply action. A decision not to act in relation to a particular matter may be considered policy. Inaction may be the policy. But a policy declared but not implemented may not be a policy in fact; it may be no more than a declaration of presumed intent - which may, or may not, be put into effect as actual policy. ...
>
> Environmental policy includes a variety of issues for negotiation and cooperation among nations. Specific environment-related agreements have been consummated and often honoured, but policy also includes prospective policy relating to problems beginning to attract international attention, problems such as global climate change which governments have declared their intention to consider.[37]

With pressures from scientists and environmentalists, policy-makers are increasingly faced with the challenge of anticipating possible environmental degradation that may occur. They are expected to take action designed not only to minimise existing environmental impacts, but also to avoid the appearance of new environmental problems, through preventative rather than curative approaches. This requires foresight which sometimes involves considerable scientific and technical uncertainty, as the solution of one environmental problem today can become the problem of tomorrow.[38]

One of the main issues for the development of international environmental law is the multilateral treaty. This is a treaty between three or more states, either on a regional or a world-wide basis.[39] Global environmental problems such as air pollution, global warming, acid rain and depletion of the ozone layer cannot be solved by a single country. Indeed, pollutants from a few countries can damage the whole globe. Cooperation between countries is, therefore, very important in solving environmental problems. Resulting from a change in the environment in the 20th century, caused or influenced by human activity, environmental issues have appeared, arousing social concerns and creating problems, leading to political action.[40] Establishing regulations to tackle environmental problems on a local or national level is difficult, but at least there is a state structure for making decisions and enforcing them on dissenting groups. This is not applied at the international or global level, because there is no world government with authority for legislation among many states. Moreover, the atmosphere and much of the oceans do not come under the jurisdiction of any one state. A state cannot legally be forced to obey an international law to which it does not subscribe. In any case, there is no international police force to enforce any environmental laws. Thus international regulations tackling global environment or resource problems typically need to be adopted and implemented by consensus among a large number of states.[41]

As for efforts leading to consensus among different opinions, there have been efforts at the international level through a succession of conferences. Conferences affecting environmental policy have often mixed scientific and political considerations. Their outcomes are political, but often informed and modified by scientific evidence. Caldwell[42] outlines the positive and negative elements of environmental conferences as follows:

Positive elements :

1) Stimulation of awareness of issues affecting all or most nations
2) Opportunity for airing grievances and revealing hidden tensions, and
3) Obtaining agreement among nation-states sufficient to afford a basis for cooperative action, including research and institutional arrangements.

Negative elements:

1) Opportunities for inflammatory rhetoric and distortion of issues for purposes of propaganda

2) A tendency to compromise issues to a point of inaction, and

3) Uncertainty regarding the ability of governments to honour conference commitments.

1-2-2. Development of International Environmental Policy

International conferences play a major role in negotiations over environmental problems by narrowing the gap between different opinions. The development of international environmental policy described in this section focuses on the two major conferences - the Stockholm Conference in 1972 and the Rio Conference in 1992.

The United Nations Conference on the Human Environment known as the 1972 Stockholm Conference was the peak of efforts to place the protection of the biosphere on the official agenda of international policy.[43] The Stockholm Declaration, as a result of the conference, is generally regarded as the foundation of modern international environmental law.[44] Prior to the conference, there had been continuous cooperation on international environmental concerns. Several United Nations specialist agencies had taken up various environmental problems, such as the conservation of fisheries, radioactive contamination, oil pollution from ships, and the impact of pollutants on human health. Efforts towards international cooperation on environmental matters also concerned aspects of the biosphere visibly threatened by the growth of human populations and industrialism. The earliest conventional forms of international environment-related cooperation were established to clarify jurisdiction and manage the uses of international waters, especially boundary lakes and rivers.[45]

The Stockholm conference added the environment to the array of global policy problems on the agenda of the United Nations. The conference theme, "Only One Earth," conveyed the importance of addressing many threats to the natural environment in a comprehensive and integrated manner in the organs and agencies of the United Nations.[46] The conference differed from other United Nations conferences in its initiation of a sequence of positive measures that have turned resolutions into actual accomplishments. The positive outcome has been the principal distinguishing feature of the Stockholm Conference. According to Cardwell, there are four factors which led to a positive outcome.

> 1) The conference from its preparatory stage was action oriented; it was intended by its managers to lead to positive results and not merely to statements of principles.
>
> 2) Preparations for the conference were extensive and thorough, with sufficient time to obtain agreements and to resolve or manage the more dangerous political differences. Accommodation among political viewpoints did not necessarily imply agreement, but rather that respective parties understood their differences and were able to find compromises that would avoid disruption of the conference.
>
> 3) Popular interest and support reinforced the sense of the necessity for the conference and its action orientation even though their direct influence upon the delegates at Stockholm was not great. ...
>
> 4) The success of the conference in achieving a positive outcome owed much to skilful management before, during, and after it. The leadership of the conference secretary-general, Maurice Strong, was consistently directed toward holding the collective effort together and focusing its deliberations on positive outcomes. The continuity of his coordinative role both in the preparatory phases, at Stockholm, and subsequently as the first executive director of the United Nations Environment Programme (UNEP) must surely be counted as a major factor in its success.[47]

The most significant outcome of the conference was the creation of the United Nations Environment Programme (UNEP) as part of a broader action plan that was proposed for addressing international environmental problems. The emergence of UNEP was one of the most outstanding developments in the realm of the international environment, becoming a prominent and effective organisation in international environmental negotiations.[48]

International organisations, such as UNEP, can play significant roles in the institutional processes of making contracts that lead to environmental regimes. A variety of international organisations become actively involved in environmental negotiations, whether they are multipurpose organisations or their purpose is limited to environmental issues. UNEP has become as an important player in developing regimes to control regional pollution, protect the ozone layer, regulate transboundary movements of hazardous wastes, and deal with climate change.[49] The work of UNEP has contributed to the global environment through a combination of inner or transboundary factors. The organisation has achieved a reputation not only for technical competence but also for strong leadership. At the same time, UNEP has followed a strategy of bringing science to bear and stressing the technical aspects of marine pollution, ozone depletion, and hazardous wastes. This strategy has served UNEP well, because the nations involved in these negotiations have found it helpful to get the political dimensions of the issues from technical aspects.[50]

Two decades after the Stockholm Conference, another major United Nations conference was held in Rio de Janeiro in June 1992. The Conference on Environment and Development, also known as the Earth Summit or ECO 92, was held from 3 to 14 June 1992.[51] The overall message of the Earth Summit is the shared recognition that all human beings have a right to economic development, but the impacts of economic activity are currently altering the planet in ways which may irreversibly damage our shared environment.[52]

The conference was not as successful as had been initially hoped in achieving binding commitments from states to take action on leading environmental problems, such as climate change and tropical deforestation. However, in the end, the conference reached compromises such as the Rio Declaration and Agenda 21, despite many worries of possible collapse by different interested groups earlier in the negotiations.[53]

During the two decades between the two conferences, several significant changes took place on the environmental level. Firstly, because of a 40 percent growth in the human population, the ecological crisis had deepened significantly. World populations continued to build up air pollutants, including those responsible for acid rain, depletion of the ozone layer, and the greenhouse effect. They also accelerated the degradation of agricultural land, diminished tropical rain forests, and exterminated countless species as a result of habitat loss, all to satisfy their desires through industrial development for a higher material standard of living in much of the world. Secondly, scientific research had contributed to a much richer understanding of what is happening to environmental systems. This research could not completely solve the problems, but at least it led to the recognition that human impacts on the environment are of a greater magnitude than expected. A third element is the evolution in thinking about the complex relationships between the environment and economic development, explained in the mid-1980s by the report, 'Our Common Future'. This report emphasised that the desperate economic plight of much of the developing world was a major cause of environmental degradation, and provided an intellectual framework for the Rio Conference. Lastly, significant changes had taken place since the Stockholm Conference in the realm of institutions and policies, both internationally and nationally. Numerous international agreements and programmes had been adopted that addressed a broad range of environmental problems, and most states now have ministries for the environment and have adopted major bodies of environmental law.[54]

Although the Conference had been described as an 'environment and development' conference, the environment was the dominant element. A great sense of urgency pervaded the 1992 Earth Summit, as reflected in its slogan, "Our Last Chance to Save the Earth." Its organiser hoped the Conference would significantly revise and strengthen the array of policies against environmental problems. The Earth Summit was a historical landmark, being the first global summit conference on environmental problems, which is indicative of the swift rise of the environment to the realm of high politics, receiving the attention of top-level officials of national governments.[55] The text of the Rio Declaration and the process which produced it provide a unique insight into the debates, compromises and achievements of UNCED.[56]

1-2-3. Negotiations on Global Environmental Issues

International negotiations on mitigating environmental problems usually succeed only after scientific opinion agrees upon the seriousness of the situation. Among various negotiated issues, two of them, ozone layer depletion and global warming, are dominant, since the seriousness of the problems and the need for cooperation have been recognised.

Concerns about ozone depletion intensified in the mid 1980s. The negotiations sponsored by UNEP to address ozone depletion, which led to three increasingly strong international agreements between 1985 and 1990, constitute perhaps the most remarkable chapter in the history of global environmental diplomacy. The first agreement, the 1985 Vienna Convention for the Protection of the Ozone Layer, was a typical framework treaty. Rather than mandating any specific reductions of the use of ozone-depleting substances, the convention simply called upon the parties to take appropriate measures to protect the ozone layer and to cooperate in monitoring, research, and the exchange of information on the ozone layer and the extent to which it is affected by CFCs and other chemicals. The next agreement, the Montreal protocol, adopted in September 1987, obliged parties to reduce production of certain CFCs and halons by 20 percent by 1993 and 50 percent by 1998, using 1986 as the base year. Developing countries were allowed a ten-year period.[57] Although the problem is not totally solved, significant progress has been made. Consequently, the ozone layer arrangement is often cited as a paradigm for the resolution of international environmental problems.[58]

The Framework Convention on Climate Change is the other major international legal instrument to address the problem of global environmental change. The message of the Earth Summit with respect to the climate problem is that emissions from energy production and agricultural and industrial activities, are changing the composition and behaviour of the atmosphere.[59]

Chronologies of the politics of ozone layer depletion and climate change are set out in Table 1-3 and Table 1-4, showing how negotiations as political actions with scientific support have developed through various international organisations and conferences.

Table 1-3. A Chronology of the Politics of Ozone Layer Depletion

Year	Events
1840	Ozone is first discovered
1973	Delegates at a conference in Kyoto, Japan discuss the suggestions that free chlorine in the atmosphere may be able to affect ozone levels in the stratosphere. (September)
1976	At the fourth session of the United Nations Environment Programme (UNEP) Governing Council, initial steps are taken to convene an international meeting to consider the CFC-ozone link. (March-April)
1977	The United states hosts the first intergovernmental meeting in Washington, DC to discuss international regulation of CFCs. (April)
	The first meeting of the UNEP-sponsored Co-ordinating Committee on the Ozone Layer is held in Geneva. (November)
1980	The UNEP Governing Council calls for reductions in the production of CFC-11 and CFC-12. (April)
1981	The UNEP Governing Council releases a statement that argues for 'the desirability of initiating work aimed at the elaboration of global framework convention for the protection of the ozone layer.' (May)
1982	UNEP convenes the first meeting of the Ad Hoc Working Group of Legal and Technical Experts for the Preparation of the Global Framework convention for the Protection of the Ozone Layer in Stockholm. (January)
1985	The Vienna Convention for the Protection of the Ozone Layer is opened for signature. (March)
1987	A UNEP meeting of scientists - convened to discuss models of ozone depletion - takes place in Wurzburg, West Germany. (April)
	The Montreal Protocol on Substances that Deplete the Ozone Layer is opened for signature. (September)
1988	The Vienna Convention enters into force. (September)
	The Ozone Depletion conference is held in London. (November)
1989	The Montreal Protocol enters into force. (January)
	European countries and the United states agree to faster CFC reductions, but developing countries oppose the new timetable, citing the prohibitive costs of substitutes. (March)
	The Saving the Ozone Layer Conference is held in London. (March)
	The First Meeting of Parties to the Montreal Protocol takes place in Helsinki. (May)
1990	The Second Meeting of the Parties to the Montreal Protocol is held in London. (June)
	The Interim Multilateral Ozone Fund is established. With its secretariat located in Montreal, its primary purpose is to provide assistance to countries of the developing world so that they can reduce their use of ozone-depleting chemicals. (September)
1991	The Third Meeting of the Parties to the Montreal protocol is held in Nairobi. (June)
	WMO and UNEP release a report that suggests that destruction of the ozone layer has advanced far more rapidly than predicted. (October)
1992	The London Amendments to the Montreal Protocol enter into force. (August)
	The Fourth Meeting of the Parties to the Montreal Protocol is held in Copenhagen. (November)
	The Multilateral Funds is established.
1993	The Fifth Meeting of the Parties to the Montreal Protocol is held in Bangkok. (November)
1994	The Copenhagen Amendment to the Montreal Protocol enter into force. (June)

Source : Ian H. Rowlands, *The politics of global atmospheric change*, Manchester University Press, 1995

Table 1-4. A Chronology of the Politics of Climate Change

Year	Events
1273	The first air pollution law to deal with the deleterious effects of fossil fuel combustion is passed in London.
1971	The first international meeting of scientists to discuss long-term climate change is held in Wijk, Sweden. (August)
1972	The United Nations Conference on the Human Environment is held in Stockholm, Sweden. (June)
1979	The First World Climate Conference is convened in Geneva by the WMO. (February)
1985	Participants in the International conference on the Assessment of the Role of Carbon Dioxide and Other Greenhouse Gases in Climate Variations and Associated Impact (held in Villach, Austria) agree that global warming could occur. (October)
1987	WMO and UNEP agree to establish an inter-governmental mechanism to assess the scientific data and to formulate response strategies for climate change. (June)
	The World Commission on Environment Report publishes its report, entitled Our Common Future (commonly referred to as the 'Brundtland Report').
1988	The first meeting of the Intergovernmental Panel on Climate Change (IPCC) is held in Geneva. (November)
	A United Nations General Assembly resolution charges the WMO and the UNEP to initiate a comprehensive review and to make recommendations on possible responses to mitigate the impact of adverse climate change, as well as on elements for inclusion in a possible future in international convention on climate. (December)
1989	Summit Meeting on the Protection of the Atmosphere takes place in The Hague. Delegates call for the formation of new global institutions to meet the challenges of global atmospheric change. (March)
	The UNEP Governing Council requests that the heads of UNEP and WMO 'begin preparation for negotiations on a framework convention on climate'. (May)
1990	The first reports of the IPCC's three working groups are released. (May)
	The IPCC reports are finalised in Sundwall, Sweden. (August)
	The Second World Climate Conference is held in Geneva. (November)
1991	The first meeting of the Intergovernmental Negotiation Committee for a Framework Convention on Climate Change (INC) is held in Washington, DC. (February)
	Meetings of the INC continue in Geneva, (June) Nairobi (September) and Geneva once again. (December)
	Leaders of over forty developing countries issue the 'Beijing Declaration', in which they reinforce their demands for resource transfers on the global warming issue. (June)
1992	The IPCC publishes its updated report.
	In New York, at the fifth INC, negotiators agree the Framework convention on Climate Change. (May)
	The United Nations Conference on Environment and Development (UNCED, or the 'Earth Summit') is held in Rio de Janeiro, Brazil. At the Earth Summit, the Framework Convention on Climate Change is opened for signature. (June)
	A meeting of the INC is held in Geneva. (December)
1993	Meetings of the INC are held in New York (March) and Geneva. (August)
	The fiftieth ratification of the Framework Convention on Climate Change is received. (December)
1994	The ninth session of the INC is held in Geneva. (February)
	The Framework Convention on Climate Change enters into force. (March)

Source : Ian H. Rowlands, *The politics of global atmospheric change*, Manchester University Press, 1995

1-2-4. Conflict against the Development of International Environmental Policy

Conflict is inherent in environmental problems, and negotiation as the process of combining conflicting points of view into a single decision follows wherever problem-solving takes place. Conflict is simply a discrepancy between two conditions or positions. To solve environmental problems means handling conflicting interests. One consideration of environmental conflict is that the existence of a problem is a predominant evidence that some parties benefit from it and have a vested interest in its continuation; problem solving then is not merely discovery and education, but dealing with party-motivated conflict. Negotiation analysts have often proposed the problem-solving approach as the best way of overcoming conflict, but that is not enough. Environmental problem-solving needs to address the means and motivations for bringing parties of having conflict of interests to the point where they can recognise problems, seek solutions, and resolve differences with other opposing parties.[60]

After the fading out of the political confrontation between capitalism and socialism, the conflict between richer and poorer countries has become one of the biggest issues in modern international relations. This conflict is even greater when it is related to environmental issues. The sources for international environmental regulations and programmes have come largely from the advanced industrial countries, which have much longer experience with the environmental crisis caused by industrialisation and the dangers that it poses to human health. For example, London had an experience of an air pollution disaster that caused more than 1000 deaths in excess of normal mortality predictions in 1888.[61] Other cities like Tokyo and New York have also had pollution related disasters in the middle of the twentieth century. These episodes emphasise the need in these countries for much stronger environmental rules and for government agencies created specifically to carry out national environmental policies.[62]

Similarly, in modern society, rich nations cause major global environmental problems despite their proportionally smaller populations. The inhabitants of these nations consume far more of the Earth's resources than the rest. The richest one-quarter of the world's nations consume about 60 percent of its food, more than 70 percent of its metal and energy, and 85 percent of its wood. These nations also generate over 90 percent of all hazardous and industrial waste and release more than 80 percent of all ozone-depleting chlorofluorocarbons into the atmosphere.[63]

In spite of their major responsibility for the problems, industrialised countries hope that developing countries adopt sustainable models of development, because their own survival is conditional upon it. Developed countries fear that developing countries are following the historical development example of the wealthy industrialised states, thereby imposing unsustainable pressures on the environment.[64] Even though developing countries perceive this, they are sure to follow blindly the richer countries because of the pressure to satisfy the fundamental desires of their populations, if there are no aids to avoid the unsustainable pressures upon the environment.

The increasing environmental consciousness throughout the developing world ran up against the economic realities of the 1980s.[65] However, the most immediate environmental problems facing developing countries are different from those associated with the affluence of rich countries. Problems of developing countries now include unsafe water, inadequate sanitation, soil depletion, indoor smoke from cooking fires and outdoor smoke from coal burning, while developed countries face problems such as carbon dioxide emissions, depletion of stratospheric ozone, photochemical smog, acid rain and hazardous wastes.[66]

The developing world has been decidedly less enthusiastic about the development of global environmental governance since the environment first appeared on the agenda of the United Nations in the late 1960s. At the time of the Stockholm conference, policy-makers from developing nations approached the environmental issue with both a lack of interest and suspicion. This is because economic development was a much higher priority for their societies than preserving the environment. Some people even expressed the view that polluted air over rapidly growing urban areas was a welcome sign of modernisation.[67] Growing international environmental concerns push developing countries to take up sustainable development models to save the globe, but these countries cannot simply follow the suggestions because of the co-existing pressure to deliver their populations from poverty.

1-3. Environmental Issues and Buildings

1-3-1. Environmental Impacts of Buildings and the Construction Industry

Buildings have great potential to affect global environmental issues, such as the greenhouse effect, acid rain and ozone depletion.[68] Large quantities of carbon dioxide and other greenhouse gasses, produced by using energy during building operations and many manufacturing processes, are on such a scale that they must be taken into consideration. The modern building industry has also placed huge demands on the ecological system by using large quantities of timber during construction, leading to the depletion of forests that had played a vital role in maintaining the natural balance.[69] CFCs are used in buildings, as refrigerants, fire extinguisher systems or in foamed insulation. Among commonly used insulation materials, only expanded polystyrene is CFC-free.[70] Some other environmental problems have been pointed out recently. Building-related transport is seen as a planning and social issue, and the embodied energy of materials is seen as an issue for materials suppliers.[71]

So far as carbon dioxide is concerned, about 50 per cent of all carbon dioxide emitted is directly related to our use of buildings. In particular, most electricity generation relies upon the burning of fossil fuels. People with an interest in buildings can help to mitigate global warming now by using energy more efficiently. In the United Kingdom, for example, the energy with that used for domestic appliances and office equipment, amounts to about half of total energy demand. The proportion of energy-related CO_2 emissions is a similar proportion.[72] Many factors influence energy conservation, from the degree of thermal insulation to the efficiency of services plant and even the aspect and configuration of the building. Energy is used for the heating of space and water, the cooling of space, ventilation, lighting, passenger lifts and so on in various buildings.[73]

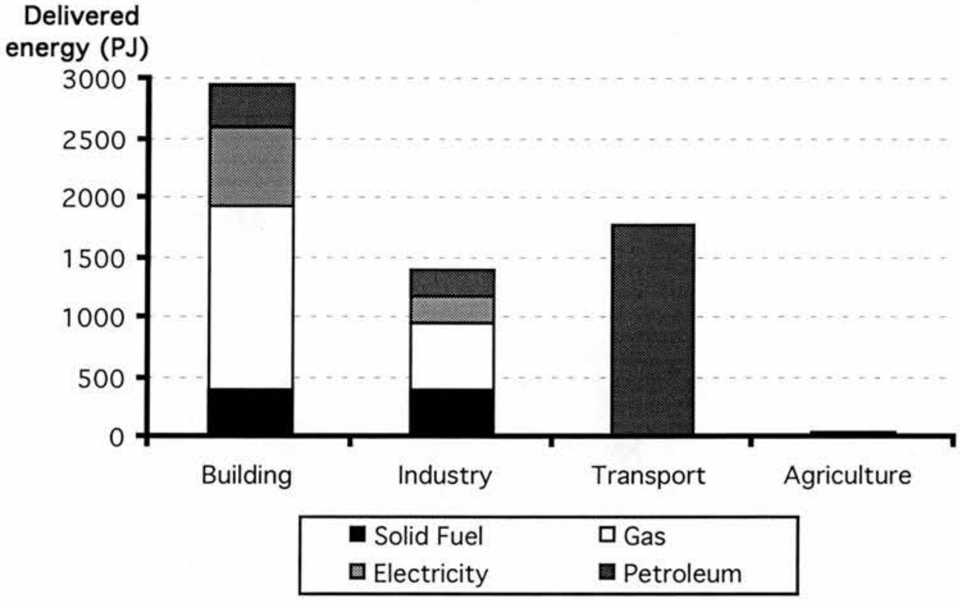

Figure 1-2. United Kingdom Delivered Energy Consumption by Sector and by Delivered Fuel Type (1987)

Source : G. Henderson and L.D. Shorrock, **Greenhouse-Gas Emissions and Buildings in the United Kingdom**, BRE Information Paper, IP 2/90, 1990

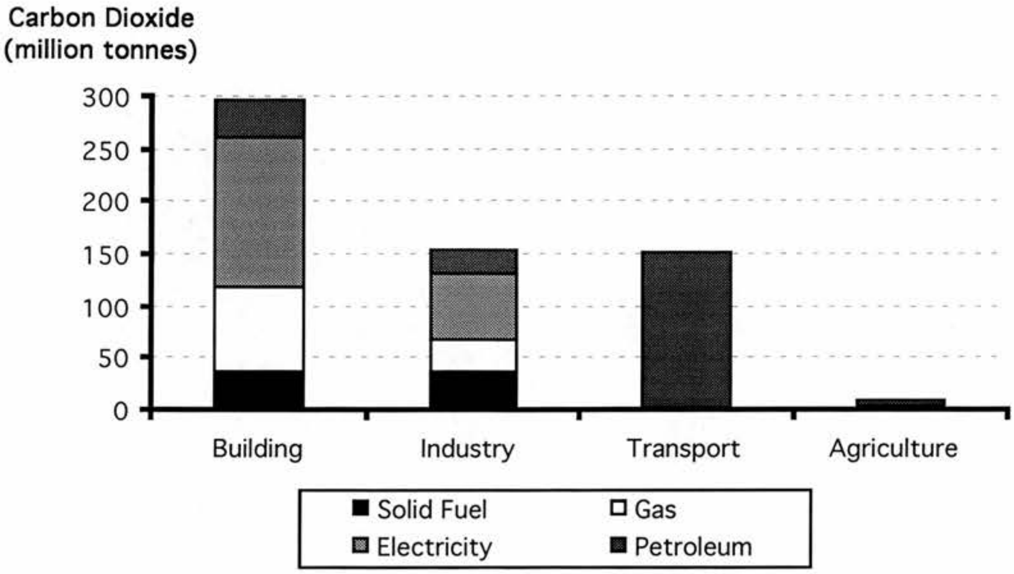

Figure 1-3. United Kingdom Carbon Dioxide Emission by Sector and by Delivered Fuel Type (1987)

Source : G. Henderson and L. D. Shorrock, **Greenhouse-Gas Emissions and Buildings in the United Kingdom**, BRE Information Paper, IP2/90, 1990, p2

Similarly, 50 per cent of the ozone-depleting chlorofluorocarbons (CFCs) is used in buildings as part of the air conditioning or refrigeration systems, in fire-extinguishing systems and in insulation materials throughout the world.[74] CFCs are also used in building components including some packaging foams, aerosol sprays and soft furnishings. As CFCs result in depletion of the ozone layer, the solution that initially presents itself is to avoid using them. There are a number of ways in which the use of CFCs in buildings can be minimised, from the substitution of CFCs with other materials, to the adoption of a different design solution. An example of the use of another material is that of choosing mineral fibre thermal insulation rather than one of the CFC-blown insulation such as extruded polystyrene.[75]

The construction industry is gaining a somewhat infamous reputation for causing adverse effects upon the environment, not only directly from its own activities, but also indirectly from industry it supports through its resource demands.[76] Construction is a large consumer of resources, with massive amount of raw materials being extracted from the natural environment and consequently waste accumulates beyond nature's capacity. Furthermore, raw materials such as wood require energy when being converted to building components. Ecosystems are especially changed by the construction of big buildings. Concrete mass and a lack of trees have an influence on regional climate change, causing an urban greenhouse effect.

As a result of the accumulation of buildings, it is difficult to find effective models for future sustainable development for cities. The urban sprawl, especially in the USA, is transport intensive. Fisk[77] states that the historic cores of major European cities with their pedestrianisation may be walkable, but could also be driving out commercial activity that sustained them without compensating with tourist income. The continuing tendency is to spread development and to travel. People are not spending any longer per day travelling, but on average we are getting further in the time spent travelling.

A polluted environment can also have an influence on building components. Building materials, especially stone and certain metals, are adversely affected by acid deposition, particularly in urban and coastal areas. Current research indicates that oxides of nitrogen and sulphur are responsible for the deterioration of stones and metals, carbon dioxide results in problems with concrete, and ozone and photo-oxidants adversely affect plastics and paints. Car exhausts are thought to be the major contributor to this deterioration in urban areas. Unfortunately, there is no conclusive evidence to provide a link between emissions and deterioration, but research is currently underway.[78]

People recognise that increasing indoor and outdoor pollution including CO_2 concentration, combined with energy-saving measures like innovation in ventilation systems and tighter building envelopes, help make buildings easy concentrators of pollutants. This raises questions about what constitutes environmental health and comfort. It is also beginning to be known through research that the design, initial commissioning or lifetime maintenance of environmental performance is inadequate in too many buildings.[79] Through this recognition, there are efforts for green architecture in modern society.

1-3-2. Green Architecture Issues

The construction industry constantly overrides nature rather than interpreting and balancing itself with nature. Some efforts may have been made in the environmental management of construction through eco-architecture and eco-engineering but, in the main, the construction industry is driven by financial considerations that preclude environmentally sound solutions being avidly sought.[80] Environmental management systems are fundamental and essential to the demonstration of environmental management. An environmental management system creates the necessary framework and structure within an organisation to ensure that its activities meet with current environmental legislation and that the environmental effects of its business are recognised and actively managed. An environmental management system is important to an organisation, not simply because it provides continuity and uniformity of environmental response, but because it enables the organisation to produce an environmental spirit within which policies, objectives and goals are formed and procedures and instructions carried out.[81]

Ecologically sound buildings and structures are technically achievable and may be more economic to construct, run and maintain than traditional solutions. They can use sustainable or man-made materials, be designed to use minimal and renewable energy and be developed on existing rather than new construction sites. Whilst some developments have demonstrated such empathy, they are just a few.[82] Moreover, identifying the action that needs to be taken is not straightforward, while environmental issues are increasingly accepted as part of the everyday life for architects and their clients.[83]

The awareness about the environmental impact of the construction industry increased dramatically through being measured by the coverage of environmental issues in the construction industry's own professional and technical press in the late 1980s. However, it quickly peaked in 1990 and then fell back, even though environmental concern about global warming and depletion of the ozone layer has deepened.[84] Although concern for green issues is now widespread in architecture as well as elsewhere, there is little the architect can depend upon for support in order to help put into context the various attempts now being made to design in green ways. For some designers this means retreating from mass production and high technology in favour of a sophisticated method, while for others the mass industrial and scientific techniques that have contributed to our various ecological crises are seen as crucial for solving them.[85]

In order to satisfy residents of buildings, understanding of requirements is essential for architects. Buildings vary according to their type and their residents, so it is difficult to reach a single conclusion. Generally, building should satisfy present users as well as future requirements and avoid environmental impacts. Attributes of successful buildings are well described by David Fisk, chief scientist at the Department of Environment. The followings are some examples;

1) Integration of building and human systems. Design is traditionally stronger on building than use. The brief can become the yardstick for post-occupancy surveys of usability.

2) Resources and adverse impacts minimised. Overspecification occurs in environmental systems, floor loading, materials choice and so on. Design for building management and monitoring in use are key aspects.

3) Simple, capable of upgrading, avoiding unnecessary complexity. Simple application of technology with the capacity to accommodate or be upgraded for space-use intensification is likely to be most effective.

4) Economical of time in operation. More thought is needed on the dynamic operation of buildings, not just spatial layout. Such studies should not just look at changing rates of occupancy but also at how habits, attitudes and behaviour influence the way systems work.

5) Respond rapidly to change. For occupants, this involves both the design and the facilities-management performance, from lift response times to reconfiguration for new work groups.

6) Sufficient management resources for the routine and unpredictable. Building-management resource requirements are often underestimated or ignored by designers. Briefing and design should make systems less complex and more self-managing. Management resource shortages are common in cases of sick building syndrome.

7) Comfortable and safe most of the time, with rapid management backup. Design must integrate automatic and manual control, and anticipate likely change.

8) Avoid introducing failure pathways. Make buildings fail-safe, or at worst fail-soft. Think through failure modes.[86]

Apart from the social requirements described, some strategies for green architecture are required in this era when so many unstable environmental situations are threatening human beings and nature. In practice, the principle of precaution should result in the minimisation of man-made material and energy flows. Some scientists believe that it is possible to reduce energy and material flows by a factor of 10 per service unit within 50 - 100 years without affecting standards of living. Achieving this aim can be assisted by sustainable design of buildings with a long lifespan that are easy to maintain, and adaptable to new fashions and behavioural patterns.[87] There are several ways in which architects can influence the energy demands of the built environment without extra costs. For example, buildings can be oriented towards the south to benefit from solar gain, and windows can be enlarged on the southerly elevation and reduced in size on the north, in moderate temperature regions.[88]

Some issues are concerned with the adverse effects of consuming raw materials. Construction is very resource-intensive, and specification decisions can have implications around the world. Steel for frames fabricated in the UK may be sourced in China and the frames re-exported to Hong Kong. Materials selection that fully reviews health and environmental effects should trace each material from cradle to grave - from materials extraction through processing, manufacture, use maintenance and disposal. Clearly this is an impossibly complex process for all materials during routine design.[89] One of the few clear points is recycling. Today, only around four percent of the mass building materials of demolition waste are effectively recycled.[90] Another point is eco-labelling providing systematic environmental information about materials and products, supporting informed decision-making and encouraging producers to address environmental issues. Building materials can have a huge impact on the environment, from winning the raw materials and producing building elements and transporting them to points of manufacture and construction; to storage, construction, use within the life of a building, maintenance, demolition, reuse or recycling, biodegrading and dumping. At every stage of the life-cycle the environmental effects may be felt on many levels with buildings; local, regional, continental and global and in short, medium and long terms.[91]

A question emerges about how to define green building material or what makes one material greener than another. Six criteria described by David Turrent can be used to assess materials in terms of environmental impact as follows:

1) Impact on the global environment (greenhouse gas emissions such as CO_2, SO_2, NOx);
2) Impact on the local environment through winning the material - mining, felling;
3) Impact on the local or global environment resulting from processing the material;
4) Embodied energy content, the energy consumed by winning, transporting, processing;
5) Heath hazards associated with processing, fabricating or preserving materials;
6) Life expectancy of the material and its potential for re-use or re-cycling in the future.[92]

Health and environmental issues should now be important criteria for assessing every construction project. Designers are faced with increasing client expectations, yet lack clear design guidance. This is made worse by the differing interpretations of scientific advances by government, NGOs, international corporations and others. The concept of specification can be interpreted broadly, ranging from individual materials and components to the regional scale - the realm of environmental impact assessments.[93]

Sustainability issues are also future oriented. As one of the efforts for the future, the result of the Vision 2000 project 'The Building Environment' looked at how technical, social and commercial changes affect buildings, their occupancy and their environmental impacts. It took the view that sustainability and more efficient construction can be complementary, with a shared interest in waste reduction. They said that too often building performance is sub-optimal. Complexity in design and operation is the most common thread, often carried out to achieve flexibility. The resulting burden of building management, however, means a simpler building would often be more effective. [94]

The environmental design agenda has gradually been shifting away from the negative such as not using energy, not polluting the environment; to the positive, such as enjoying the letting in of more natural light and air. Comfort was often narrowly defined as the absence of discomfort.[95] Creating green buildings requires not just higher technical standards for energy efficiency or reduced environmental impact, but green attitudes. However, little has been said about the ethical and philosophical changes today's designers are required to make. The issue of sustainability represents a major discontinuity in the flow of the modern movement. In Western countries, there is a shift from being nations which have been encouraged to consume more in order to support the economy; they are now being coerced into adopting an attitude of conservation in order to save the planet. Cultural change is needed throughout the building industry - change which affects how we design, what we design and specify, and how and why buildings are constructed. Unlike other man-made goods such as cars and televisions, buildings not only embody energy and other resources but also carry the investment across generations. It is now no longer acceptable to see buildings merely as products to be consumed and replaced within a generation. Buildings, and the cities of which they form an essential part, are reservoirs of compacted energy and resources handed down across centuries.[96]

1-3-3. The Life-cycle Approach for Sustainable Architecture

As the seriousness of the impact of the construction industry on the environment has grown, sustainability issues for architects have been developed in various ways. Since buildings last for a long time and require a sequence of maintenance activities compared to other industrial goods, the impact on the environment through the life of our building should be taken into account. There have been many efforts to measure the environmental impact of buildings through their life-span.

S. P. Halliday suggested the necessity for a life cycle approach for designing environmentally benign buildings, minimising the adverse environmental impact of building in use, refurbishing buildings and ultimately disposing of them in an environmentally sound way.[97] She suggested seven stages for the whole life of a building: 'pre-design, design, preparing to build, construction, occupation, refurbishment and demolition'. In each stage, legislation, guidance, rules of thumb, pitfalls, new ground and unresolved issues are discussed with some recommendations.

The Swiss Community of Interests for Building Biology/Building Ecology (SIB) has made eco-labelling through the life cycle stage.[98] In the first eco-label design by Bosco Bueler, January 1991, three stages such as Rohstoffe (Materials), Verarbeitung (Utilisation) and Abbruch (Demolition) were evaluated. Each stage has three steps. Through the second eco-label designed by Heinz Frick in 1994, the final version was designed by Bosco Bueler again in 1995. The final eco-label for building products has four stages: (1) manufacture, (2) utilisation, (3) maintenance and (4) disposal. Each stage has two steps: (1) Raw materials mining/Harvesting Primary Energy and Producing/processing distribution for Manufacture, (2) Construction installation and use/cleaning for Utilisation, (3) Renovation and Demolition/re-construction for maintenance and (4) Re-use or recycling and Deposition/ Incineration for Disposal.[99] In each step, environmental impacts are assessed to green (low environmental impact), yellow (medium environmental impact) or red (high environmental impact) categories.

Summary of the Chapter

As environmental concern on the international level has deepened, there have been many efforts to sustain the globe in various areas of concern. Human activities have been the main cause for destruction of natural eco-system, but efforts to solve the problems also have played a role in sustaining the globe. Scientists help politicians who deal with the global environment by providing some proofs of environmental changes, while politicians try to improve the situations either with technical assistance or by opposing current trends which are against the natural environment. Through organising international conferences, there has been improvement in negotiations over environmental problems by narrowing the gap between different opinions. However, solutions depend on handling conflicting interests among different parties, such as developed and developing worlds.

As well as the construction industry, buildings, which were originally designed for protecting people from harsh environments, have had a great impact on the environment in various ways. Along with other areas, efforts by architects for solving environmental problems have developed, as the recognition of these problems have disseminated. These efforts from architects are interrelated to many other subjects such as social and political situations, economical and technical possibilities, understanding scientific phenomenon, etc.

Although targets for sustainable future may be identical, proposed solutions vary according to social and political situations. They also depend on diverse subjects, which require different approaches to the target. Recognition and understanding of these roles, which are described in this Chapter, forms the foundation for assessments of and suggestions for a certain type of building, high-rise apartments. In order to understand regional situations for high-rise apartment developments, background of environmental conditions and high-rise apartment developments in Korea will be analysed in the next two chapters. These backgrounds, along with the understanding of current global environment described in this chapter, are important sources in an environmental impact assessment of high-rise apartments (EIAHA) in Korea.

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Chapter 2.

Environmental Movement and Policy in Korea

Even though Korea has a long history of nearly five thousand years, the situation of Korea in the twentieth century is quite different from that in previous centuries. Korea was not an independent country for most of the first half of this century, being controlled by Japan between 1910 and 1945. After regaining its independence, Korea experienced an even worse internal situation, being divided into two countries, South and North. The saddest part of its history then followed, when a war between the two Koreas broke out in 1950 and lasted three years, making both Koreas amongst the poorest areas in the world. When this unstable period ended, South Korea entered a new era of a fast-growing economy. Enormous economic growth has resulted in Korea not having to worry about bread, but about quality of life, for most of the population. Despite providing wealth in economic terms, fast industrial development inevitably leads to environmental degradation through the pollution of air, water and the natural ecosystem.

The previous chapter presented general environmental problems from a global perspective. This chapter deals with one specific country, Korea, and is divided into three parts. The first part of this chapter is an overview of current Korean conditions, from a natural and social perspective, to understand the current Korean situation, focusing on the dynamic changes during the second half of this century. These natural and social trends are closely related to the construction industry. The second part is about the environmental conditions and movements over the last few decades. This is mainly based on Government statements, and people's reactions to the Government's attitude. The last part of this chapter analyses environmental regulations and policies after describing the governmental organisations with regards to the environmental crisis. Cooperation with and response to other countries is presented as a part of Korea's environmental policy.

2-1. General Overview of Korea

2-1-1. Natural Environment

Korea is a peninsula which is located in the far east of Asia between China and Japan. The land area of Korea (both South and North) is about 220,000 square kilometres, of which South Korea covers about 99,000 square kilometres. (cf., the United Kingdom: 244,000 square kilometres, England: 130,000 square kilometre and Scotland: 79,000 square kilometres). Forest land, which mainly consists of mountains and hills is about 65.5 per cent of the total land area in South Korea, whilst 21 per cent of the land is taken up by agriculture, 3.3 per cent is built up area for housing, industry and public facilities. The remaining 10.2 per cent is covered by water and other areas. Although the forest area has been slightly reduced, it still occupies a substantial portion of the whole country, largely in the mountains and hills. Therefore it is difficult to develop cities and industrial areas in these upland wooded regions.

Korea, with its many mountains and clean rivers, is a country with many natural assets. People enjoy the benefit of a natural environment in four distinctive seasons, as the weather in Korea is influenced by the Pacific Ocean in summer and by the Asian continent in winter. Therefore, the climate of Korea is typified by monsoon summers with a rainy season and by continental winters with freezing weather. Annual mean temperature ranges from 6 °C to 16 °C and annual precipitation from 1000 to 2000 millimetres. Seasonal changes are gradual and distinctive: the temperature range between the hottest and the coldest month is around 25-30 °C (Seoul: -3 °C in January ~ 25.4 °C in August).

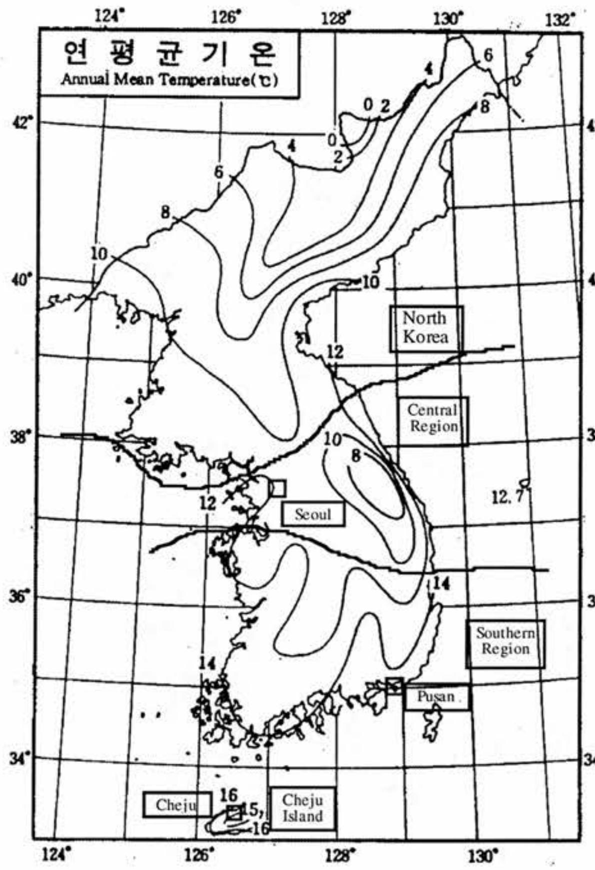


Figure 2-1. Annual Mean Temperature Chart in Korea

Source : Korea Meteorological Administration, *Annual Climatological Report*, 1992.

The country is divided by temperature into three regions - Central, Southern and Cheju Island. Cheju Island is located in the far southern sea and therefore has a semi-tropical climate. The temperature of these three parts in summer is nearly the same, while that in winter varies dramatically according to the regions. The central region of the country, including Seoul, has the most dramatic temperature changes. Monthly mean temperatures in Seoul (central part), Pusan (southern part) and Cheju (Cheju island) are shown in Figure 2-2. For a reference, that in London between 1941 and 1970 is shown as well.

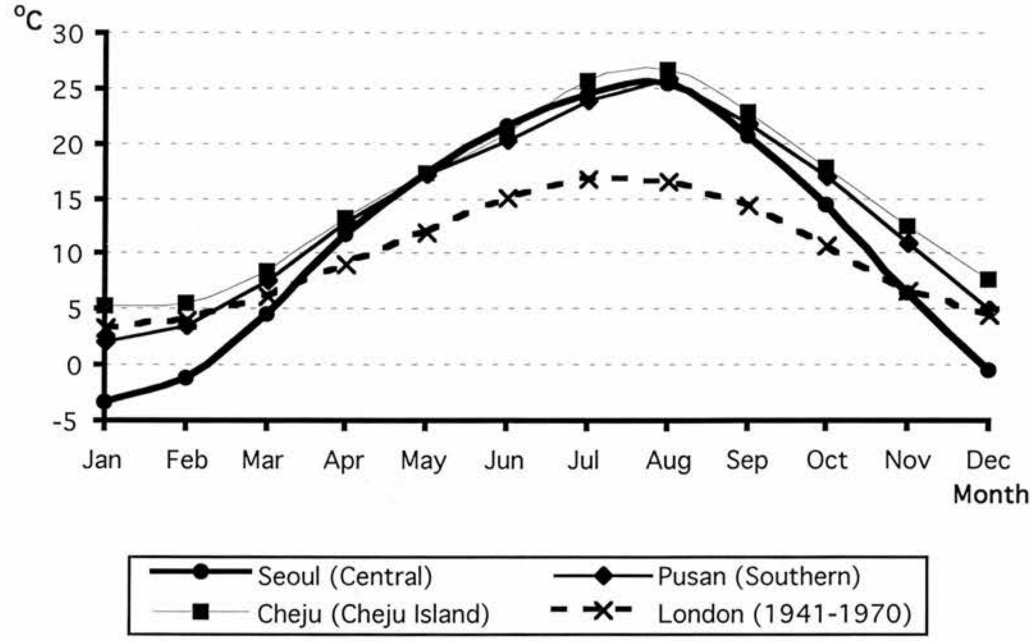


Figure 2-2. Mean Monthly Temperature by the Region

Source : Korea Meteorological Administration, *Annual Climatological Report, 1989-1994.*

The weather in Korea changes dramatically throughout the year, thus creating the need of heating and cooling when a building is designed. Weather conditions in summer can even be uncomfortable because of high humidity which requires dehumidification. Furthermore, concentrated heavy rain usually only comes in summer. Hot humid summers in Seoul require cooling in buildings for about two months of the year, which can be accomplished by proper passive ventilation or electric fans, although the number of housing units having air conditioning is increasing steadily. However, this also has an advantage, because a lower sunshine ratio in summer than in winter is a merit for accepting or avoiding direct solar energy for indoor air temperature. Heating is required almost six months a year, demanding big loads in January and February. Even though the weather in winter is below freezing point, the sky is normally clear and there is plenty of sunshine, and the sunshine ratio in winter is higher than that in summer. A traditional house faces south in order to gain the maximum amount of sunshine in winter and has a good ventilation system to combat hot and humid summer weather. The design method of a traditional house in relation to the climatic conditions should be used in the designing of sustainable buildings for modern Korean housing.

Mean, average maximum, and average minimum temperature by month in Seoul in 1992 are shown in Figure 2-3. The figure of the temperature range in 1992 is the most similar to that of an average year in the 1990s, while that of 1993 was too low and that of 1994 was too high. (See Figure 2-5 for details)

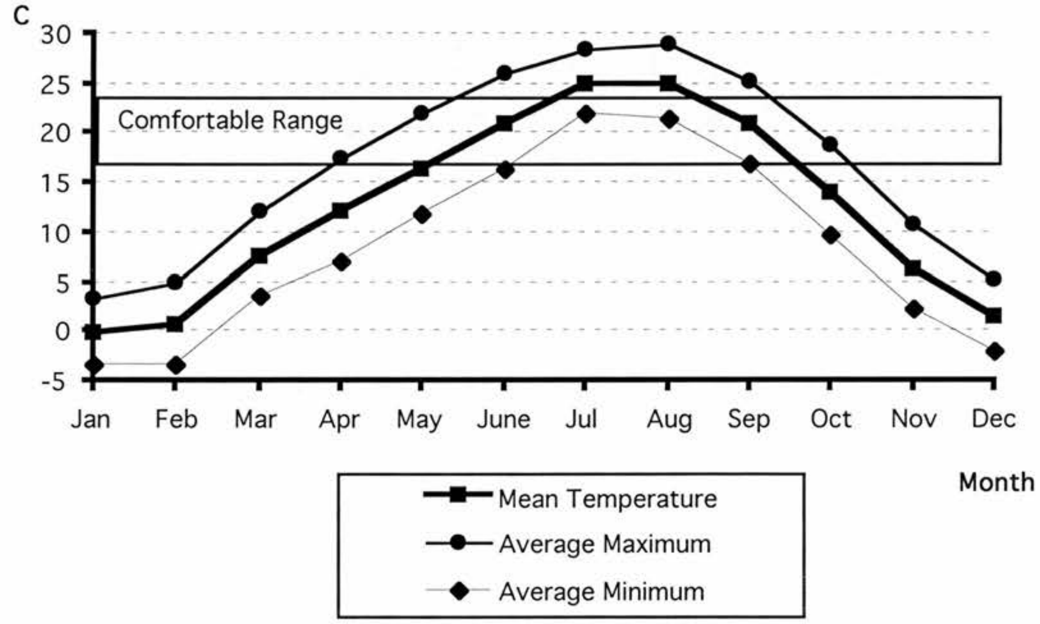


Figure 2-3. Mean, Average Maximum and Average Minimum Temperatures in Seoul in 1992

Source : *Annual Climatological Report 1992*

Besides air temperature, there are more climatic elements for passive design for buildings. Important elements are relative humidity, sunshine ratio, and total sunshine hours. Average relative humidity in Seoul is around seventy percent, and relative humidity in summer is higher than in winter, reaching up to around eighty percent in July. High temperatures of around 30 °C on summer afternoons accompanied by high humidity, creates very uncomfortable conditions. Urban areas in Seoul paved with cement, concrete and asphalt, have caused even greater temperature increase. Most public buildings, offices, stores, and shops have air conditioning systems, operating throughout summer for two or three months, whilst there are not many air conditioners in residential buildings, but families with them have been increasing recently. Sunshine ratio[1] and actual sunshine hours in winter are higher than in July. This is the greatest advantage for passive solar heating in winter, and most residential buildings are designed to get the maximum amount of sunshine in winter, while avoiding overheating in summer. The sunshine ratio and sunshine hours in April and October is very high, so well designed buildings can avoid using auxiliary heating systems in these months. The figures for average relative humidity, sunshine ratio and sunshine hours in Seoul between 1990 and 1994 by month are shown in Figure 2-4.

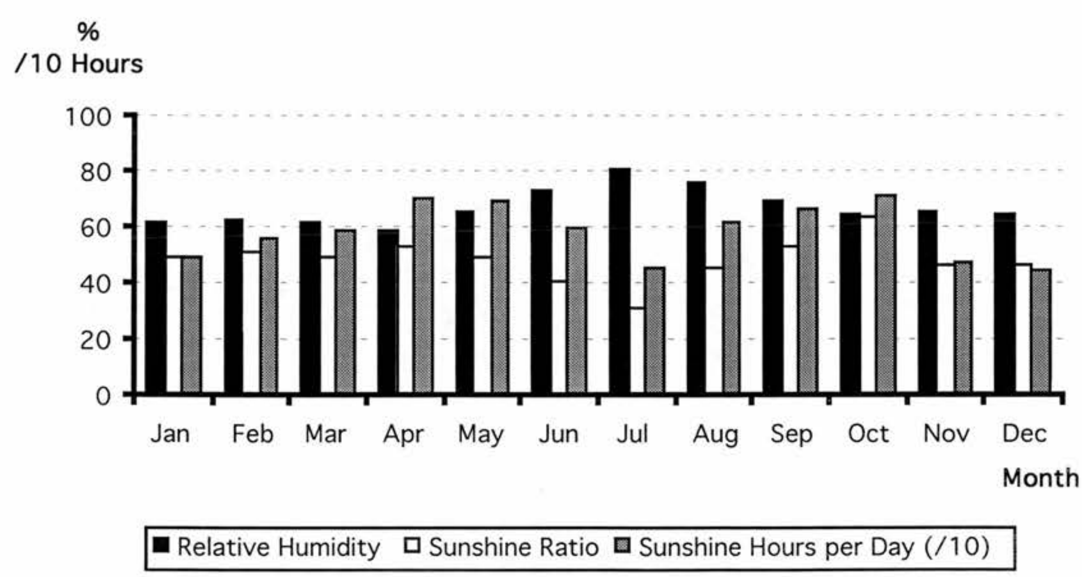


Figure 2-4. Average Relative Humidity, Sunshine Ratio and Sunhshine Hours per Day by Month in Seoul between 1990 and 1994

Source : *Annual Climatological Report 1990 - 1994*

The weather nowadays is warmer than in the past years, especially in winter time. Annual mean temperature between 1961 and 1990 was about 0.4 °C higher than that between 1931 and 1960 for the country as a whole. Temperature variation in big cities like Seoul, Taegu and Ulsan is around 0.6-0.7°C, while rural areas such as Ullung Island and Chupungnung have no such apparent temperature variation over the years.[2] The temperature in the 1990s is much higher than before, especially in the Seoul metropolitan area and other urban areas. The trends of temperature change are shown in Figure 2-5. This may be said to be a part of the global warming phenomenon, a major issue in global environmental changes, as mentioned in chapter 1. It could also be argued that cities have great impact on regional temperature changes, because of built-up environments and traffic.

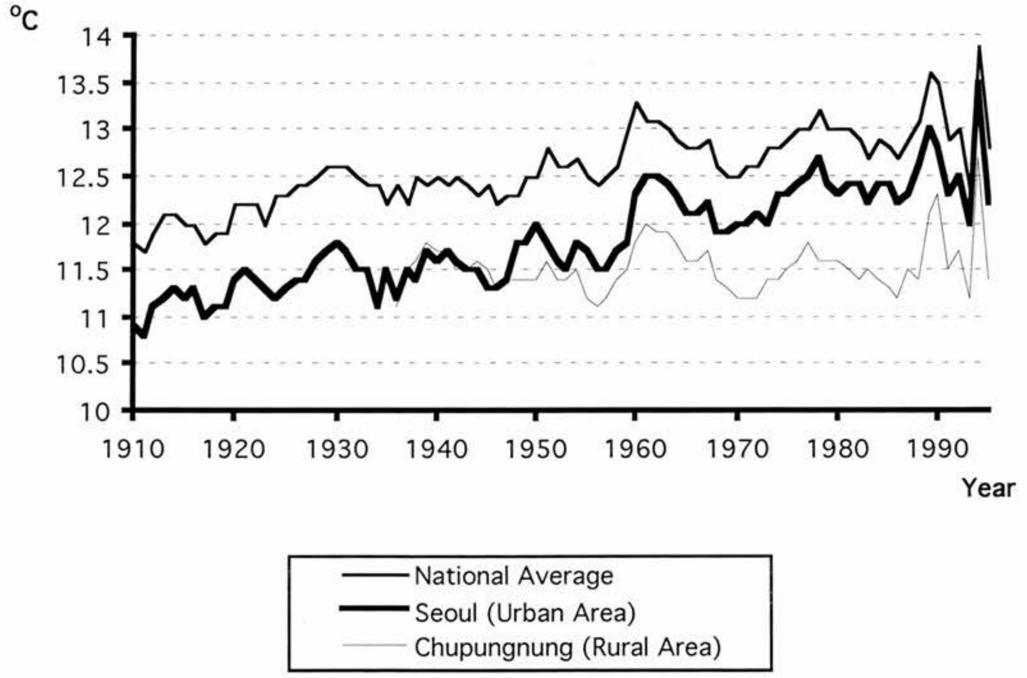


Figure 2-5. Trends of Mean Temperature in Urban and Rural Areas

Source : Korea Meteorological Administration, *Global Warming*, 1991 & Korea Meteorological Administration, *Annual Climatological Report, 1989 - 1994*

Another important element for solar design is the latitude of Seoul, which is 37°N. The angle between the sun and the ground at noon is 76.5° in June, while that in December is 29.5°. Wind is usually moderate with average wind speed between 1.5 and 3 metres/second throughout the year. Stronger winds come in April and May, while there is less wind in September and October. Winter winds mostly come from the west or north west affected by Siberia, whilst summer winds usually come from the east or south-east.[3] This may be one of the reasons that the number of east facing houses exceeds those west-facing.

2-1-2. Population Trends and Cities

The population of Korea was 45.18 million in 1995.[4] The population density is 451 people per km^2 and that of cultivable land area is about 1200, which indicates that Korea is one of the most densely populated countries in the world. However the rate of population increase dropped drastically from 2.9% per annum in 1960 to 0.98% in 1990.[5] The population by age, therefore, has changed. The percentage of over-sixties has increased, while the percentage of under-fourteens has decreased. Population concentration in urban areas is now a serious problem, especially in and around Seoul.

With economic growth stimulated by industrial development after the Korean War, the population movement from rural areas to major cities was continuous until the end of the 1980s, especially in the capital region, where the population trend has been more dramatic. Seoul has over twenty percent of the total Korean population in just 0.6 % of the land. With almost 11 million people, Seoul has become one of the biggest cities in the world today. Compared with the 2.5 million population in 1960, the population has more than quadrupled in only 35 years by 1995. The population density per square kilometre was 17,791 in Seoul. People started to move out of the capital in the 1990s, and the trend of moving to the outskirts of the Seoul area continues to increase. The population in and around this area (around 10 per cent of the total land area) is now 46 % of the total. Thus, the decline of Seoul's population should be considered alongside the expansion of Seoul's Metropolitan Area. The percentage of people in Seoul and the surrounding area is shown in Figure 2-6.

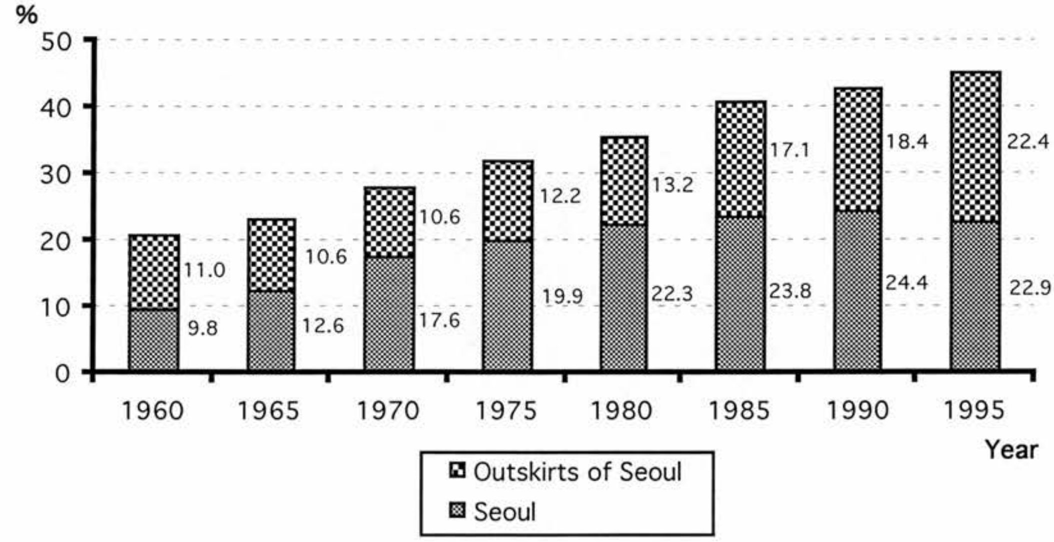


Figure 2-6. Percentage of Total Korean Populations in Seoul and Capital Region

Source : KNHC, *Housing Statistics 1994* &
Daily newspaper, *Korean Herald 31 March 1996*

Family organisation has also changed significantly. Young couples tend to live separate from their parents, which was not common in the past. Therefore, accompanied by a reduction in family size, the number of families established has increased faster than the size of the population. Young couples tend to move to big cities, even if their home towns are relatively small cities or in rural areas, leading to an increasing demand for housing units in big cities. Undoubtedly, the price of the land will rise, causing buildings for housing to become higher and denser to produce many units in a relatively small area.

The process of urbanisation appears to be a big problem, even though the rate of population growth in big cities has declined significantly since the middle of the 1970s. Urbanisation will have a greater impact on values, institutions, social controls, human behaviour, economic activities, organisations and the environment, as well as on the role of the government. It has already led to many problems, such as housing shortages and traffic congestion, as well as pollution problems.

2-1-3. Economic Growth and Welfare

Since 1960, the Korean economic growth has been remarkable, with an average annual Gross National Product (GNP) growth rate of more than 7%.[6] Here, Korea has developed from being one of the poorest agricultural countries with a small economy a quarter of a century ago, to being one of the leading and most dynamic countries among the developing nations. The GNP per capita exceeded ten thousand US dollars in 1995, while it was just US$ 253 in 1970.[7] The period of the late 1980s is the most significant one in Korea's recent development history. Real GNP grew at 11.3% per year between 1986 and 1989, and per capita GNP nearly doubled for only three years from US$ 2,194 in 1985 to US$ 4,127 in 1988.

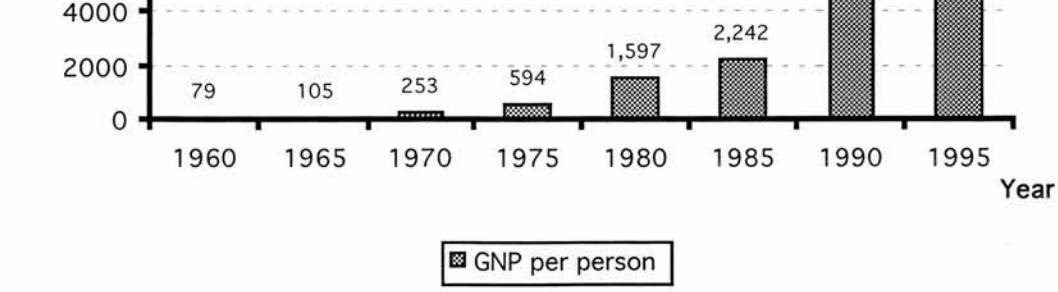


Figure 2-7. Trends of GNP per person

Source : *Korea through Statistics 1995*, pp 314-315

& Daily Newspaper, *Hankuk Ilbo 21 March 1996*

The nation's health facilities, health workers and professionals have been steadily augmented to meet the health needs of the population. Along with this increase, the ratio of hospital beds per unit of population and the ratio of health workers and professionals to population have improved greatly. Hospital beds increased from 16,538 in 1970 to 38,096 in 1980 and 141,267 in 1989. Population per physician decreased from 2,159 in 1970 to 824 in 1994.[8] This improvement of health facilities and workers has resulted in Korean people living longer than before. Life expectancy from birth is now more than seventy, compared with less than sixty only a few decades ago. The increase of elderly people has become a social issue, not only because of the lack of facilities, but also because of the changing attitude toward elderly people and family organisation.

To help people access medical treatment, the Medical Insurance Law was enacted in 1963, and amended in 1976. The medical insurance programme now being implemented is divided into three schemes; medical insurance for industrial workers, medical insurance for government employees and private school teachers, and medical insurance for the self-employed. More than 90 percent of the whole population is covered by these medical insurance programmes, and the remainder will be covered by a medical aid and subsidy programme, resulting in a 100% coverage for medical care security.[9]

2-2. Environmental Conditions and Movements

2-2-1. The State of the Environment

The growth of the industrial sector has been the basis for Korea's overall economic prosperity. However, this success has been accompanied by environmental degradation. Firstly, industry extracts materials from natural resources and produces both products and pollution in return, and secondly, industrial activities have always caused pollution. The government has made special efforts to improve the condition of the environment since it received public attention, so Korean environmental conditions are now being improved.

Although a certain degree of environmental pollution could be observed in the 1960s, environmental deterioration did not receive sufficient attention. During the 1970s, some people began to express concerns about environmental degradation. However, such concerns were not given sufficient attention due to the government giving priority to industrial development. In the middle of the 1980s, a new explicit environmental conservation goal was introduced as part of the official aim of national economic development.[10] This historic turning-point, a government-led effort to upgrade the priority given to environmental protection, was especially commendable because it was accomplished in a relatively short period of time. Since the late 1980s, new and precise action programmes covering many fields and sectors have been especially devised and implemented.

Air

In modern society, people have a great desire for living in a healthy environment because the environmental conditions of the modern world are deteriorated with increasing to industrialisation. However, if the environment is controlled properly, people can live in healthy conditions even in a heavily industrialised society. Modern governments, therefore, try to have an effective policy to control the environment. Governments try to make and achieve environmental standards, especially with regards to air quality, because the increase of air pollution cannot be reduced purely through individual efforts. In Korea, the government provides six air environment standards - SO_2, CO, NO_2, dust, O_3, and Pb for better air quality.

Table 2-1. National Environmental Standard for Air

Item		National Environmental Standards
Sulphur Dioxide (SO_2)		Yearly average 0.03 ppm or less Daily average 0.14 ppm or less Hourly average 0.25 ppm or less
Carbon Monoxide (CO)		8 Hours average 9 ppm or less Hourly average 25 ppm or less
Nitrogen Dioxide (NO_2)		Yearly average 0.05 ppm or less Daily average 0.08 ppm or less Hourly average 0.15 ppm or less
Dust	Total Suspended Particulate(TSP)	Yearly average 150$\mu g/m^3$ or less Daily average 300$\mu g/m^3$ or less
	Minute Dust (PM-10)	Yearly average 80$\mu g/m^3$ or less Daily average 150$\mu g/m^3$ or less
Oxidants (O_3)		8 Hours average 0.06 ppm or less Hourly average 0.1 ppm or less
Lead (Pb)		3 month average 1.5 $\mu g/m^3$ or less

Source : *Environment White paper 1995* , p44

The establishment of a standard for SO_2 took place in February 1979; for CO, NO_2, O_3, TSP and HC in August 1983; and for Pb in February 1991. These standards have been in operation ever since. Some items like SO_2 and CO had achieved the original standards so the Government consolidated the standards in 1994. Likewise, the standard of HC was excluded at the end of 1993. Different air pollutants come from different sources; the pollutant emissions like SO_2 and TSP mainly come from manufacturing processes, and those like HC, NO_2 and CO from transportation.

Since 1980, there have been many efforts to reduce air pollution in the big cities. Low sulphur fuel oil was first supplied in 1981, and the use of coal for heating commercial and office buildings and clustered housing was prohibited. In 1988, the use of pollution-free LNG was required for new commercial and office buildings as well as clustered housing. Therefore, the pollution rate of SO_2 in Seoul and Pusan, which previously exceeded the limit (0.03 ppm or less), has been reduced to under the acceptable limit.[11] The trends of the average yearly SO_2 pollution rate in major cities are as follow:

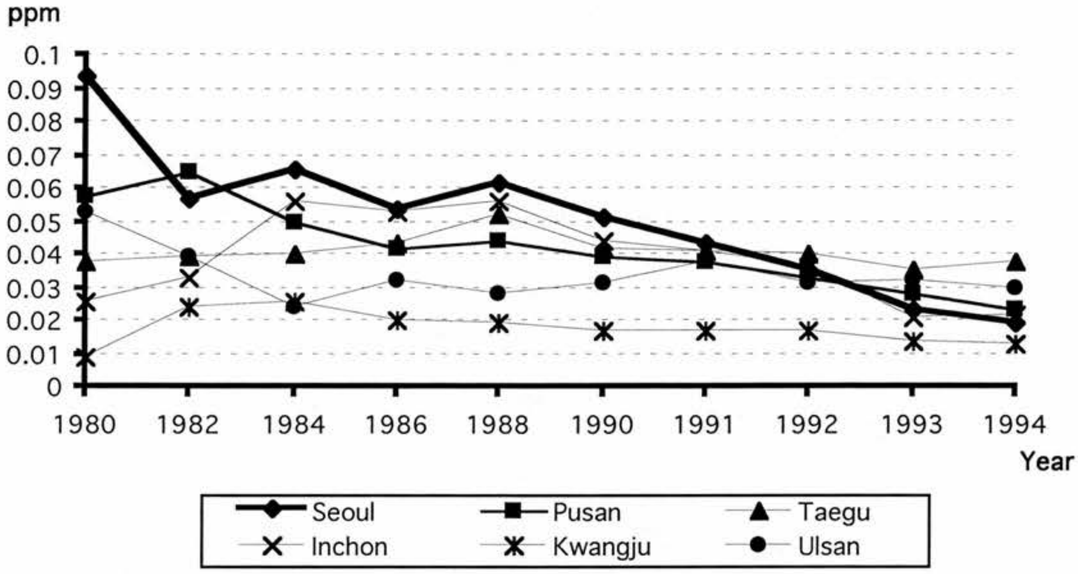


Figure 2-8. Trends of Yearly Average Sulphur Dioxide in Major Cities

Source : *Environment White Paper*, 1995 p36

The SO_2 pollution rate in winter does, however, often exceed the daily standard of 0.14 ppm in big cities. Reducing the heating load and using clean fuel are required for the improvement of the SO_2 pollution rate in winter.

The level of Total Suspended Particulate(TSP) in main cities has also been reduced since the setting of the environment standard criteria in 1983. In Seoul, TSP has decreased from 210 $\mu g/m^3$ in 1984 to 78$\mu g/m^3$ in 1994, which is less than the standard level, 150$\mu g/m^3$. Every other city also reduced the level of TSP to less than the standard level in 1994.

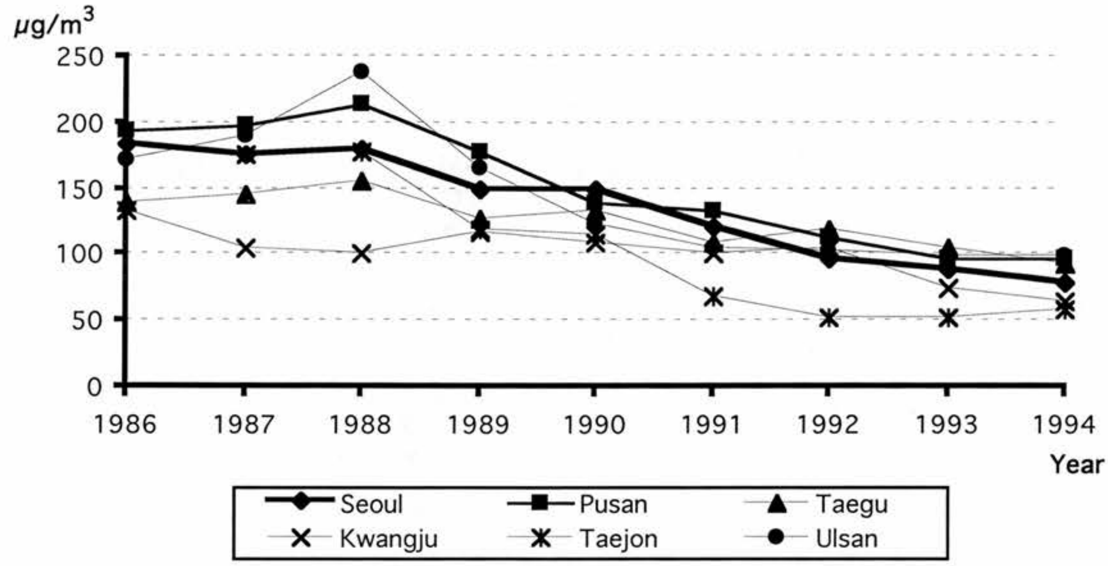


Figure 2-9. Trends of TSP in Major Cities

Source : *Environment White Paper 1995* p38 and *1992* p70

Rainfall is naturally slightly acidic, but where air is polluted with oxides of sulphur and nitrogen, rainfall produces strong sulphuric and nitric acids. So-called acid rain has a pH level of 5.6 or less. Acid rain inhibits plant nutrition and consequently restricts the range of plant and animal life, as freshwater can become poisonous to plants, fish and other animals. Furthermore, acid rain damages buildings.

The monitoring of acid rain began in July 1983, and there were 42 automatic measuring points in 30 main cities in Korea at the end of 1992. The degree of acidity in rainfall in 1994 was found to be low in Pusan, Ulsan and Seoul, but normal in other cities.

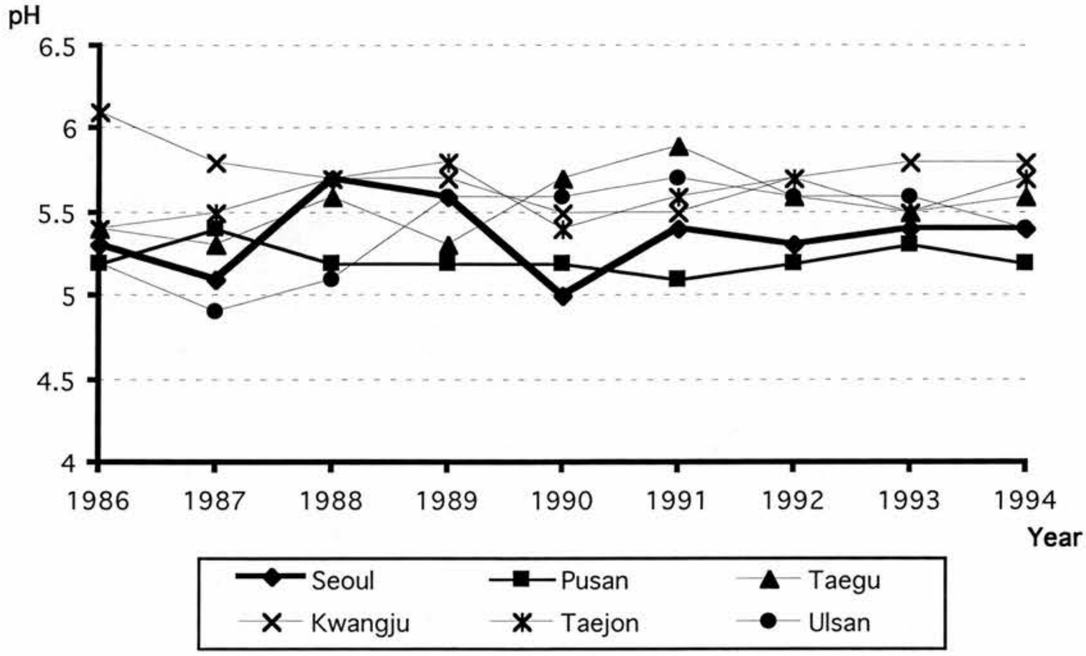


Table 2-10. Trends of Acid Rain in Major Cities

Source : *Environment White Paper 1995*, p40

The observed level of other pollution materials is shown in Table 2-2. They have been measured in 78 measuring points in 31 main cities. They were all within the National Environmental Standard in 1994. It seems that the air in Korea is reasonably clean, indeed the statistics show it has improved, but in spite of this, many Korean people continue to complain about the degradation of the air. Some people claim that the method of measuring is not accurate enough to show the true conditions, and others say that the measuring points are badly chosen. For example, one air measuring point in the city centre of Seoul is in a park area. Although this park is just next to a heavy traffic road, the pollution level will be different in those two places. Nevertheless, the park acts as the measuring point for the heavily polluted road.

Table 2-2. Air Pollution Levels of Major Cities (1994)

(Unit : ppm)

City	Substance	NO_2	O_3	CO
	Standard	0.05/ Year	0.06 / 8 hours	8.0 / 8 hours
Seoul		0.033	0.014	1.5
Pusan		0.024	0.014	1.6
Taegu		0.023	0.015	1.1
Kwangju		0.022	0.015	1.2
Taejon		0.019	0.014	1.4
Ulsan		0.026	0.014	1.1

Source : *Environment White Paper 1995*, p42

Water

In Korea, the average yearly rainfall is 126.7 billion m^3. However, 57 billion m^3 of this total is lost due to evaporation and submersion, which leaves us with water resources of only 69.7 billion m^3 per year. Two thirds of the rainfall falls between June and September, so most of the water resources are lost in floods. Thus, water which may be used amounts to only 15.8 billion m^3 of river water and 9.6 billion m^3 of dam water. About 1.8 billion m^3 of underground water is used per year, making the total amount of water used a year 27.2 billion m^3. Out of this 27.2 billion m^3, water for living is 4.7 billion m^3 (17%), water for industry is 2.5 billion m^3 (9%), water for agriculture is 15 billion m^3 (56%) and water held in reserve is 5 billion m^3 (18%).[12]

Due to population increase and better living standards, sewage water has increased. In 1994, an average of 14.6 million m^3 of sewage water was discharged each day into rivers and coastal waters. In addition, an increase in livestock farming has significantly contributed to the deterioration in the quality of river water. Due to better treatment of the sewage water and industrial waste water, water quality in the principal rivers has improved since 1988. However, the story in 1994 was different because of drought. Because of only half of the normal level rainfall in some regions, pollution level in main rivers increased in 1994.[13]

Most of the rivers in Korea flow into the Yellow Sea, a semi-enclosed sea. Therefore, the coastal seas near major harbours and estuaries on the western coast of Korea are seriously polluted compared with other seas. The Yellow Sea is shared with China, a recently industrialising country. Most of the newly industrial sites in China are also located near the Yellow Sea, which will make it one of the most polluted oceans in the world. Cooperation is therefore necessary between China and Korea in order to preserve the Yellow Sea.

Sea water on the southern coast maintains first-grade sea water quality, below the level of COD 1.0 mg/l. However, Masan-Chinhae bay, the semi-enclosed sea near the heavily populated and industrialised cities of Masan, Changwon and Chinhae, is severely polluted. Korea's eastern coastal sea area is, in general, not polluted. But the harbour areas of ports like Sokcho, which is an enclosed sea, have experienced some severe pollution problems.

Waste

The discharge of municipal solid waste is steadily increasing in quantity as the quality of people's lives improves. In 1991, an average of 92 thousand tonnes of solid waste was produced per day in urban areas, an increase of about 9.8 % over the previous year. This statistic means that every Korean person in an urban area produces 2.3 kg of solid waste per day.[14] This trend has changed since 1991. The amount of waste has been enormously reduced mainly due to a reduction in coal briquettes being used as a fuel. The main heating fuels are now oil or gas rather than coal.

The other means of reducing waste is to levy a special commercial duty on all waste; i.e., people should pay money according to their amount of waste. Total waste in 1994 was 147 thousand tonnes: this was less than 1991, when the amount of waste reached a maximum of 158 thousand tonnes, but slightly more than 1993. The increase was due to industrial waste, especially construction waste. General waste, produced by houses, offices, etc., has steadily decreased since 1991. General waste production per person per day decreased from 2.3 kg in 1991 to 1.3 kg in 1994. After imposing a commercial duty for waste, the amount of waste was reduced by 40 % and the amount of waste recycled increased by 100%.

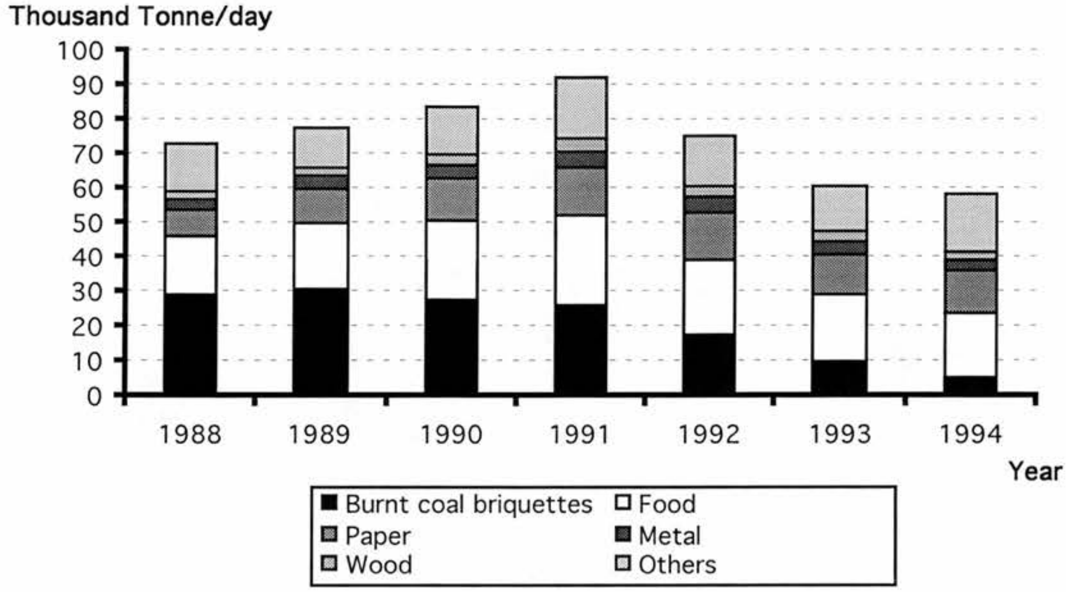


Figure 2-11. General Waste Produced per Year

Source : *Environment White Paper 1995*, p191

Today, more than half of all waste is buried underground. The overall amount of waste buried has been reduced, while the amount of waste recycled in 1994 increased by 42.8% compared to the previous year.[15] However, the re-cycling rate of general waste was only about 15% in 1994, but has a target of 30 % by 2001.

2-2-2. Energy and the Environment

Energy is essential for economic growth but energy production and use are the major causes of environmental degradation. The rapid growth of the Korean economy has been accompanied by a remarkable increase in energy consumption. Energy consumption in 1994 was almost ten times that in 1967. During this whole period, there was only one year when the use of energy was less than that of the previous year. This was in 1980, when the second oil crisis occurred, resulting in massive price increases. The increase in the use of oil and energy in the 1990s is rising yet more sharply as the price of oil in the international market remains steady. In 1994, oil consumption in Korea even exceeded that of the United Kingdom, whereas in the 1970s and 1980s Korea's oil consumption was much less than that of the United Kingdom.

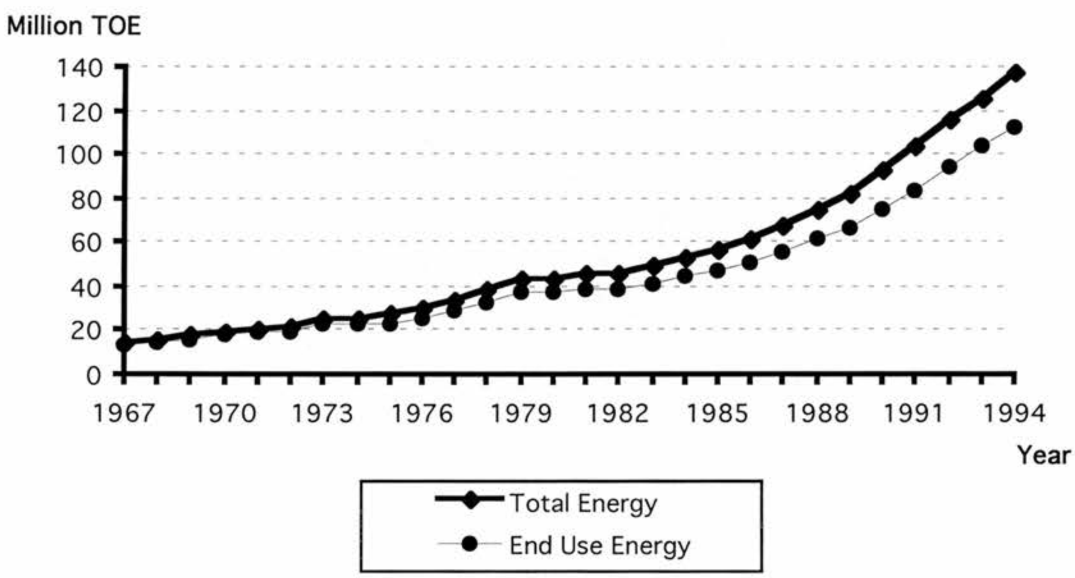


Figure 2-12. Trends of Energy Use

Source : Ministry of Trade, *Yearbook of Energy Statistics 1995*, p14

The rate of energy consumption increased rapidly around seven percent per year in the 1960s and 1970s in Korea, along with rapid economic growth. The growth rate was reduced to around four percent per year in the early 1980s, because of world energy fluctuations. From 1986, however, annual energy consumption has increased rapidly again, so energy consumption in 1993 is nearly double that of 1986.[16]

Concerning energy supply, less than one percent was domestic production, and the rest was imported in 1993. Therefore it is vital to reduce energy consumption in buildings, as well as in industry and transportation.

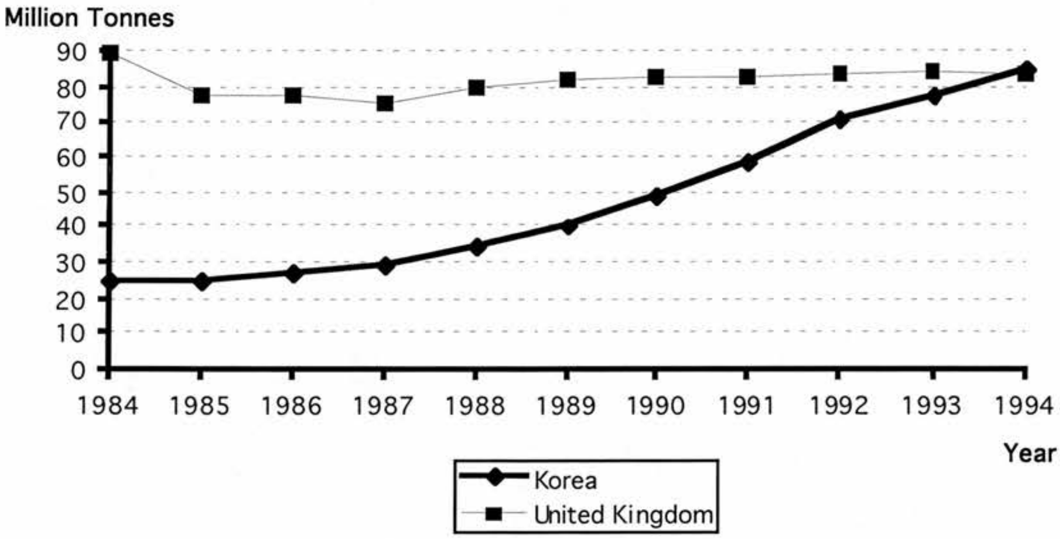


Figure 2-13. Trends of Oil Consumption in Korea and the United Kingdom

Source : Ministry of Trade, *Yearbook of Energy Statistics 1995*, pp 274-275

After the first oil crisis, energy policies concentrated on securing oil supplies and reducing oil consumption. After the recovery from the first crisis and during the second oil crisis, energy policy objectives focused on the diversification of oil supply sources, rationalisation of the energy supply mix, and overseas resource development. Since the mid-1980s, work in the following has included: long-term power development plans, the promotion of efficiency in energy use, active overseas resource development, the improvement of price structures, the promotion of energy R&D, and the structural adjustment of energy industries.

A remarkable change has occurred in structure as well as in volume. When Korea was an agricultural country with a small economy in 1965, Korea's main energy need and consumption was for heating homes, and these needs were then met by anthracite briquettes and firewood. In the 1970s, the use of petroleum increased substantially, reaching a peak in 1978 when it accounted for about 63.3% of total energy consumption.[17]

Table 2-3. Trends of Energy Consumption in Korea

Unit : Thousand TOE
(%)

	1982	1985	1988	1991	1994
Prime Energy Consumption	45,625	56,296	75,351	103,622	137,235
	(100)	(100)	(100)	(100)	(100)
Coal	15,450	22,022	25,162	24,535	26,680
	(33.9)	(39.1)	(33.4)	(23.7)	(19.4)
Petroleum	26,312	27,142	35,390	59,627	86,343
	(57.6)	(48.2)	(47.0)	(57.5)	(62.9)
LNG	-	-	2,718	3,503	7,618
	-	-	(3.6)	(3.4)	(5.6)
Hydro	501	915	892	1,263	1,025
	(1.1)	(1.6	(1.2)	(1.2)	(0.7)
Nuclear	944	4,184	10,025	14,078	14,663
	(2.1)	(7.4)	(13.3)	(13.6)	(10.7)
Firewood & Others	2,417	2,031	1,164	617	906
	(5.3)	(3.6)	(1.5)	(0.6)	(0.7)
Final Energy Consumption	38,711	46,998	61,033	83,803	112,206
	(100)	(100)	(100)	(100)	(100)
Industry	17,354	20,014	28,200	42,914	59,909
	(44.8)	(42.6)	(46.2)	(51.2)	(53.4)
Residential & Commercial	15,197	18,180	19,700	21,919	25,968
	(39.3)	(38.7)	(32.3)	(26.2)	(23.1)
Transportation	4,215	6,707	10,747	16,156	23,860
	(10.9)	(14.3)	(17.6)	(19.3)	(21.3)
Public & Others	1,945	2,096	2,385	2,813	2,469
	(5.0)	(4.4)	(3.9)	(3.3)	(2.2)

Source : Energy Management Cooperation, *Energy Saving Guidebook 1991*, p84 & Ministry of Trade, *Yearbook of Energy Statistics 1995*, pp 14-31

Established in the late 1970s, power generation from nuclear sources has increased enormously since the mid-1980s. The end need of energy consumers has also changed. The percentage of energy consumption in the transportation and industrial sector has increased, while that in the other sectors has decreased. For the residential and commercial sector, the rate of energy consumption has decreased, but total energy consumption has increased steadily.

In order to improve environmental quality in the energy sector, activities such as the continuous promotion of energy conservation and efficiency improvements, the expansion of district heating systems, encouragement of combine heat and power in major industrial parks, and the adoption of energy impact statements will be promoted as well as the continuation and strengthening of existing energy conservation measures. To encourage wider use of clean energy, greater use of Liquefied Natural Gas (LNG), low sulphur fuel and unleaded gasoline is encouraged. The development and dissemination of energy technologies are also being promoted. Finally, the expansion of demolition of facilities for coal fired plants will continue.

Degradation of the environment nowadays is much faster than before, because of the increase in energy consumption. The production and use of fossil fuels such as coal, oil and natural gas are major sources of local air pollution, and also of regional and global problems such as acid rain and the greenhouse effect. As mentioned previously, the air quality of big cities in Korea has been improved, although the use of energy has increased. This is mainly due to the use of better quality fuel, reducing sulphur dioxide, nitrogen oxide, etc. However, what we should pay greater attention to is CO_2 emissions which is the main cause of the global warming. Unfortunately, there is no governmental regulation for reducing CO_2 emission, although some pressure groups are putting pressure on the Government through their publications.

2-2-3 Public Awareness and Citizen Participation in Environmental Issues

Non-governmental environmental groups play important roles in the promotion of environmental awareness, education, and public participation. Though some of them are financially supported by the government, most of them are self-supporting private organisations. The number of Non-governmental environmental groups at the end of 1992 was about 130, and this number increased to more than 200 groups in 1995[18]. The oldest such organisation is the Korea Nature Preservation Association whose membership includes professors, teachers and journalists. It has been active in the wildlife protection movement. The Korea Environmental Preservation Association is run by business people and environmental engineers, and conducts environmental education for engineers and business managers, as well as public awareness programmes for the general public. The Association has published many booklets as well as an official monthly environmental magazine which is distributed free of charge.

The Korea Resources Recovery and Re-utilisation Cooperation was established in September 1980. Its main functions are to collect and recycle waste plastics, waste paper, scrap iron and used pesticide bottles. The Environmental Management Corporation was established in May 1987. It provides loans for the installation of pollution control facilities, operates combined environmental conservation facilities, and operates facilities for specified hazardous material disposal, wastewater treatment plants at industrial complexes, nightsoil treatment plants, etc.

There are also several well-known private environmental activist groups in Korea like the Anti-Pollution Movement Association and the Friends of Nature. The Anti-Pollution Movement Association has been engaged in various activities such as the investigation of pollution damage, protests against businesses which cause pollution, and the promotion of a pollution free society through education and awareness. The Friends of Nature emphasise the importance of ecological conservation, and conduct activities such as the protection of aged trees, forests and wildlife reserves.[19]

Newspapers represent people's concern about the environment and have a role to play in educating how people perceive it. From the end of the 1980s, there has been a dramatic jump in the number of news items about the environment, with reports carrying in-depth stories on diverse topics. In 1992, the number of news items about the environment in eighteen national newspapers was 8,884.[20] A non-governmental environmental group named Church Environment Research Institute has published collections of newspaper material concerning peace and the environment every year since 1982. This book, published in 1993, reported that environmental items in 1992 were nearly double that of 1991.[21] The number of news items in national newspapers are shown as follows;

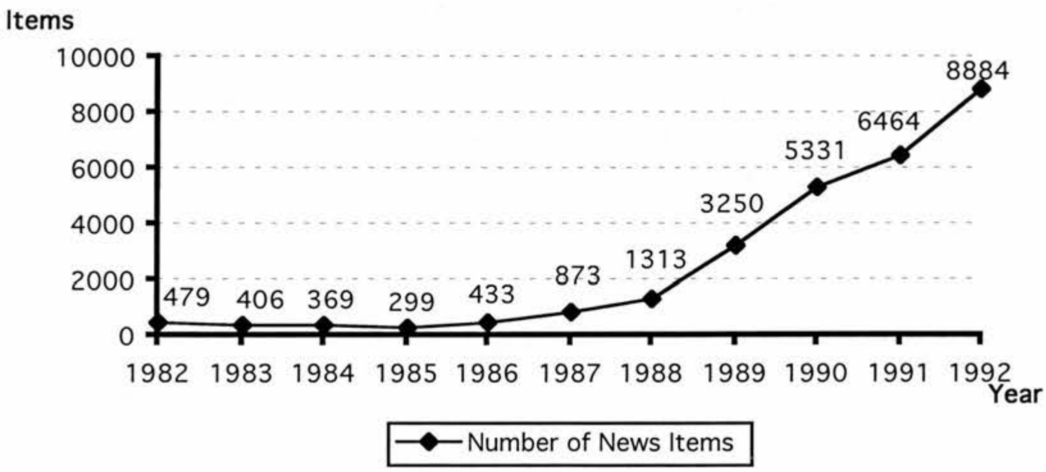


Figure 2-14. Yearly Environmental News Items in National Newspapers

Source : *Environment White Paper 1992*, p350

Environmental education is essential for the development of an environmental consciousness. However, the importance of environmental education has been largely neglected in Korea in the past, largely due to the lack of concern for environmental problems because of the priority given to economic development. Nowadays, increasing concern in the government and higher education institutes, along with the development of NGO (Non Governmental Organisation) movements, has resulted in the development of a dynamic environmental education movement.

In 1982, the government commenced research on the effectiveness of environmental education in schools. As a result of government-sponsored research, new environmental education programmes at primary and middle schools were introduced. Since 1985, the Ministry of Education has been operating 'Model Schools for Environmental Preservation' to develop effective programmes for environmental education. Four model primary schools and four model middle (secondary) schools are selected every two years from areas near to polluted regions. From 1993, model schools extended to the nation's kindergartens.[22] Therefore, ten schools, including two kindergartens, are selected every two years. These schools guide the environmental preservation programmes with the aim of influencing daily behaviour.

For curricular education, the environmental protection textbooks for primary schools, middle schools and high schools are published under the auspices of the Ministry of Education. This educational programme has been conducted within regular courses such as ethics, technologies, science and geography. In addition to these curricula, a new independent course, 'Environment', has been introduced since 1995 into middle schools. This course is not compulsory, and the selection rate for this course was only 1.6% in 1995, the year of introduction. For high schools, Environmental Science in academic high schools, Environmental Conservation in agricultural high schools, and Environmental Technology in technical high schools will commence from 1996.[23]

In higher education, more than half of the universities have departments related to environmental science or technology. Apart from these departments, most students in every other department can take lectures as general subjects.

Public education programmes such as lectures on environmental protection provide a valuable opportunity for adults to gain access to information on the environment. Such activities raise awareness of environmental issues. The Ministry of Education is currently reviewing public education programmes and several non-governmental organisations are also conducting public education activities.

2-3. Environmental Regulation and Policy

2-3-1. Governmental Organisation

The Ministry of the Environment has the primary responsibility for environmental policies and policy implementation under the present Government Organisation Act. The duties of the Ministry of the Environment are to establish environmental and emissions standards, environmental policies and programmes; to monitor and conduct research on environmental pollution; to manage environmental facilities; to oversee treatment of toxic chemicals; to conduct environmental impact assessments; to preserve natural conservation areas and to resolve environmental disputes.[24] The Ministry of the Environment also has the authority to coordinate other ministries' regulatory functions which may have an adverse environmental impact. The Environment Preservation Committee has the final coordinative power. The Committee is chaired by the Prime Minister and consists of the Ministers of the Economic Planning Board, Finance, Trade and Industry, Construction, Public Health and Social Services, as well as the Minister of the Environment.[25]

Environmental organisations in the government never existed until the Pollution Control Division was organised into the Bureau of Sanitation and the Ministry of Health and Social Affairs in 1973. In order to achieve economic growth, environmental issues were not allowed to play a part in national policy. Even in 1973, their role was too small to improve environmental conditions. The Environmental Management Bureau was established in 1977, and consisted of three divisions - environmental planning, air and water. Since then, quality of life has become a major issue. In 1980, The Environment Administration, headed by a vice (deputy) minister level administrator, was established as an independent central government agency under the Ministry of Health and Social Affairs. The Environment Administration was upgraded to the Ministry of the Environment in 1990 and placed under the leadership of a cabinet minister. Therefore, it is only in the 1990s, at the end of the twentieth century, when environmental concerns are playing a genuine role in Korean governmental policy.[26]

The Ministry of the Environment recently expanded its sub-organisation, having seven central offices or bureaus with 30 divisions: the Planning and Management Office, the Policy Co-ordination Office, the Nature Conservation Bureau, the Air Quality Management Bureau, the Water Quality Management Bureau, the Water Supply and Sewage Treatment Bureau and the Waste Management Bureau. Each Office or Bureau has four or five divisions which deal with specific problems and topics. In the Policy-Coordination Office, cooperation with other states for solving global environmental problems are dealt with, as well as developing technology and education. The Ministry of the Environment also has four sub-organisations, three being; the National Institute of Environmental Research, the Environmental Officials Training Institute, and the Central Environmental Disputes Co-ordination Commission. There are also seven Regional Environment Offices, four of these are based on four major rivers and the remaining three are smaller sub-regional offices.[27]

The National Environmental Protection Institute (NEPI) was established under the Ministry of Health and Social Affairs in 1978, and upgraded to the National Institute of Environmental Research (NIER). The major activities of NIER are to carry out environmental research and development, to perform various tests, and to establish integrated environmental information systems in the fields of environmental health, air quality, water quality and waste management. The subjects of environmental research are: environmental health, environmental biology, environmental impact assessment, air pollution engineering, atmospheric chemistry, atmospheric physics, noise and vibration, waste water engineering, water pollution chemistry, water pollution microbiology, marine environment research, domestic waste research, industrial waste research, chemical assessment research and soil environment research.[28]

Environmental training and education was carried out by the National Institute of Environmental Research before the end of 1991. As an independent institute for environmental training, the Environmental Officials Training Institute (EOTI) was established in 1992. There are two kinds of training programmes; the Basic Training Programme and the Expert Training Programme. The former is for improving the official's ability in environmental management, and the latter is for increasing the technical knowledge and skills for environmental engineering. About twenty thousand officials and engineers took an EOTI training programme between 1981 and 1991.

Legal action and environmental disputes are increasing along with the deteriorating environmental conditions in Korea. Legal action through the courts requires considerable time and financial resources. Thus, in 1991, the Central Environmental Disputes Coordination Commission, an institutional system which can solve or mediate environmental disputes through the administrative system, was established.

Though the prime responsibility for environmental management belongs to the Ministry of the Environment, many other agencies also have authority and responsibility for environmental protection. The Economic Planning Board, which is headed by the Vice Prime Minister, exerts influence through policy coordination and the budget control process. It has recently established a special inter-ministerial committee, the Committee on Global Environmental Policy. The Board will develop and implement policies to achieve simultaneous economic and ecological sustainability in the nation's development towards the 21st century. The Ministry of Foreign Affairs has the responsibility for international cooperation through treaties and conventions. The Ministry recently established the Science and Environment Office. The Ministry of Home Affairs is responsible for environmental regulation, supervision and the nature protection movement.

2-3-2. Environmental Policy

Environmental policy mainly focuses on a better environment in the future. The economic growth rate will be as high as it has been, so the lifestyle in Korea will be quite different in the 21st century. GNP per person is predicted to reach US$ 17,000 in 2001, and makes Korea a high-income country. Population concentration in big cities looks certain to continue, and the population of the six biggest cities is expected to be more than half of the total population. In addition to these internal demographic changes, Korea's external relations with neighbouring countries will change, requiring better cooperation. From the global perspective, all nations will have a similar global policy when dealing with environmental problems.

Due to these changing circumstances, some government targets have been set: providing clean and safe water, securing clean air, using waste as useful material, creating a healthy ecological system, securing an advanced environmental maintenance system, and taking the lead in creating a sustainable global environment.[29]

In order to ensure clean and safe water, the pollution level of rivers must be lowered. The quality of water in most rivers is not adequate for drinking without any treatment, or even for industrial purposes. First and second grade water quality, which requires just a little treatment to become drinkable, currently constitutes 30 percent of the total water resources in Korea and is targeted to be 70 percent in the year 2001 and 95 percent in 2005. In order to achieve this standard, most sewage water should be treated before being discharged into rivers. Water supply facilities to most households is also targeted. Currently this figure is around 80 percent.

In order to improve public health, especially in the big cities and on industrial sites, efforts to improve air quality are now well established. Using cleaner fuel such as LNG (liquefied natural gas), the rate of sulphur dioxide will be reduced from more than 0.02 % to less than 0.01 % of the atmosphere in Seoul. To improve efficiency, the number of combined heat and power generating plants will be increased from 15 in 1995 to 45 in 2005. The rate of district heating systems, the most efficient heating system, will replace central or individual heating systems by 25.3 % by 2005. To save energy, the facilities for using heat from incinerators will be increased, and it is forecast that 34 percent of heat from them will be used in 2005. By introducing pollution free vehicles such as the electric car, monorail and light train, air pollution from traffic in big cities will be reduced.[30]

Waste has been reduced since 1991, when commercial duty for waste was introduced.[31] Through continuous education and advertisements, waste production per person per day will drop to 1.0 kg in 2005. Some 25 percent of waste will even be reused and 50 per cent of that will be incinerated and the heat from incinerators will be used as mentioned previously.

2-3-3. Co-operation with Global Environmental Protection

Environmental protection needs international cooperation. Korea, as well as other countries, has made efforts to participate in efforts to sustain the global environment. The position of Korea in the global society is somewhere between developed and developing countries. The top issue of environmental policy in Korea regarding the global society is to adopt advanced environmental technology from the developed countries.

Korea has participated in the major multilateral environmental treaties and plans to participate in more such treaties. In order to protect the Ozone Layer, the whole global society has decided to reduce and finally prohibit the use of some gasses like CFCs and HCFCs which deplete the Ozone Layer, as established in the Montreal Protocol. Korea acceded to the Montreal Protocol on 27th May 1992, and acceded to the amended treaty on 10th March 1993[32]. The accession to the Basel convention on the Control of Transboundary Movements of Hazardous Waste and Disposal took place at the beginning of 1994 along with the USA and Japan.

As for wildlife protection, Korea acceded to the convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) in July 1993. Regarding marine environmental protection, Korea acceded to Annex I and Annex II of MARPOL 73/78 and incorporated most Annex V obligations into national legislation. Korea also acceded to the London Dumping Convention which prevents marine pollution through the prevention of dumping waste materials into the sea in December 1993. UN Framework Convention on Climate Change for preventing global warming was also acceded to in December 1993.

Table 2-4. International Environmental Conventions which Korea has Joined

Name of Convention	Adopting Date (Effective Date)	Joining Date (Effective Date)
Air		
Vienna Convention for the protection of the Ozone Layer	22 March 1985 (22 September 1988)	27 February 1992 (27 May 1992)
Montreal Protocol on substances that Deplete the Ozone Layer	16 September 1987 (1 January 1989)	27 February 1992 (27 May 1992)
The London Amendment to the Montreal Protocol	29 June 1990 (10 August 1992)	10 December 1993 (10 March 1993)
The Copenhagen Amendment to the Montreal Protocol	25 November 1992 (14 June 1994)	2 December 1994 (2 March 1995)
UN Framework Convention on Climate Change	9 May 1992 (21 March 1994)	14 December 1993 (21 March 1994)
Ocean and Fishery		
International Convention for the Regulation of Whaling	2 December 1946 (10 November 1948)	29 December 1978 (29 December 1978)
International Convention for the Prevention of Pollution of the Sea by Oil	12 May 1954 (26 July 1958)	31 July 1978 (31 October 1978)
International Convention for the conservation of Atlantic Tunas	14 May 1966 (21 March 1969)	28 August 1970 (28 August 1970)
Convention on the Conservation of the Living Resources of the South East Atlantic	23 October 1969 (24 October 1971)	19 January 1981 (18 February 1981)
International Convention on Civil Liability for Oil Pollution Damage	29 November 1969 (19 June 1975)	18 December 1978 (18 March 1979)
International Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage	28 December 1971 (16 October 1978)	8 December 1992 (8 March 1993)
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention)	29 December 1972 (30 August 1975)	21 December 1993 (21 January 1994)
International Convention for the Prevention of Pollution from Ships	2 November 1973 (2 October 1983)	23 July 1984 (23 October 1984)
Protocol of 1978 Relating to the International Convention for the Prevention of Pollution from Ships	2 February 1978 (2 October 1983)	23 July 1984 (23 October 1984)
Convention on Future Multilateral Cooperation in the Northwest Atlantic Fisheries	28 October 1978 (1 January 1979)	21 December 1993 (21 December 1993)
Convention on the Conservation of Antarctic Marine Living Resources	20 May 1980 (7 April 1982)	29 March 1985 (28 April 1985)
Hazard Waste		
Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal	22 March 1989 (5 May 1992)	28 February 1994 (29 May 1994)

Table 2-4. continued

Name of Convention	Adopting Date (Effective Date)	Joining Date (Effective Date)
Natural Ecology		
International Plant Protection Convention	6 December 1951 (3 April 1952)	8 December 1953 (8 December 1953)
Plant Protection Agreement for the Southeast Asia and Pacific Region	27 February 1956 (2 July 1956)	4 November 1981 (4 November 1981)
The Antarctic Treaty	1 December 1959 (23 June 1961)	28 November 1986 (28 November 1986)
Convention on the International Trade in Endangered Species of Wild Fauna and Flora	3 March 1973 (1 July 1975)	9 July 1993 (7 October 1993)
Convention on Biological Diversity	22 May 1993 (29 December 1993)	3 October 1994 (1 January 1995)
Nuclear Safety		
Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Underwater	5 August 1963 (10 October 1963)	24 July 1964 (24 July 1964)
Treaty on the Prohibition of the Emplacement of Nuclear Weapons and Other Weapons of Mass Destruction on the Sea-bed and the Ocean Floor and in the Subsoil Thereof	22 February 1971 (18 May 1972)	25 June 1987 (25 June 1987)
Convention on the Physical Protection of Nuclear Material	3 March 1980 (8 February 1987)	7 April 1982 (8 February 1987)
Convention on Early Notification of a Nuclear Accident	26 September 1986 (27 October 1986)	8 June 1990 (29 July 1990)
Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency	26 September 1986 (26 February 1987)	8 June 1990 (29 July 1990)
Others		
Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space Including the Moon and Other Celestial Bodies	27 January 1967 (10 October 1967)	13 October 1967 (13 October 1967)
Convention Concerning the Protection of the World Cultural and Natural Heritage	23 November 1972 (17 December 1975)	14 September 1988 (14 December 1988)
Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques	10 December 1976 (5 October 1978)	2 December 1986 (2 December 1986)
International Tropical Timber Agreement	18 November 1983 (1 April 1985)	25 June 1985 (25 June 1985)

Source : **Environment White Paper 1995**, pp 538 - 547

Besides accepting global environmental conventions, there has been further development in regional environmental policies. Starting from the Korea-Japan environmental symposium between 1988 and 1991, efforts for environmental protection between Korea and Japan have made progress regarding environmental problems such as air and water quality and waste. An agreement on environmental cooperation between Korea and Japan was established in June 1993. According to this agreement, environmental policy in both countries was discussed in the first meeting in Tokyo in 1994 and the second meeting in Seoul in 1995. Between Korea and China, an agreement on environmental cooperation was established in October 1993. There was a discussion to solve Yellow Sea Pollution in March 1994.[33]

In addition to the cooperation within East Asia, there are more efforts on the global scale. Exchanges to cooperate and spread the use of environmental technology and industrial machinery between East Asia and North America and EU countries are continuing. Interchanges of information and data about environmental technology and policy have been made, as well as groups of trainees being exchanged. Cooperation with developing countries has also been taking place, with the acceptance in Korea of trainees from China, the Philippines, Thailand, and so on.

Summary of the chapter

Korea has changed enormously in the last half century, both economically and environmentally. Due to there being no corrective measures before 1980, the environment in Korea suffered as the economy grew. Consequently, people had little concern for the environment due to the desire to escape poverty. From the 1980s, people started to recognise the importance of the environment, since the pollution levels in big cities were already intolerable. As a result, governmental policy had to change to give priority to the environment over economic growth.

Thanks to the government's new priorities, regional environmental situations have been improved. Air and water quality have been upgraded, especially in the 1990s, although the rate of economic growth and energy use remained relatively high. Efforts to improve environmental quality have led to the continuous promotion of energy conservation and efficiency improvements and wider use of clean energy such as Liquified Natural Gas (LNG), low sulphur fuel and unleaded gasoline. The development and dissemination of energy technologies along with the expansion of demolition of facilities for coal fired plants have helped to improve the air environment especially in big cities.

However, new environmental issues such as global warming, ozone depletion and acid rain have appeared. These problems cannot be solved by a single country, indeed, much more international cooperation is required now than ever before. International efforts to solve these problems have led to many agreements among nations, which require each state to set up its own environmental policy for protecting the globe. Regulations on CO_2 and CFC emissions, which are the most influential gases for global warming and ozone layer depletion, have not yet been established in Korea, although Korea joined international environmental conventions for protection of the ozone layer and on climate change. This is the right time to consider global environmental changes to save human beings as well as the natural ecosystem. Most industry has a potential to save the earth by reducing energy use and waste production during the production processes.

The construction industry is no exception. Every building uses energy for construction, maintenance and operations, producing waste materials when its life-cycle finishes. Moreover the industry devours raw materials without considering their depletion. Later chapters examine the environmental impact of building construction, especially high-rise apartments in Korea. In order to give a broader picture of Korean high-rise apartments, the requirements of housing and the history of residential buildings, as well as the current trend of high-rise apartments, are described next in Chapter 3.

Notes and References

* marked after a number is written in Korean. The name of books in Korean will be shown at the end of the Bibliography.

1 Sunshine ratio is the rate of sunshine by the total sunrise hours. If the sun is in the sky for 12 hours and the actual sunshine time is 6 hours, the sunshine ratio is 50 per cent.

2 * Metheorological Office, *Global Warming, 1991*, pp 5-6.

3* Korea Meteorological Administration, *Annual Climatological Report*, 1990-1994.

4 Daily Newspaper, *Korea Herald*, 31 March 1996.

5 Ministry of the Environment, *National Report of the Republic of Korea to UNCED 1992*, p15.

6 Korea Foreign Trade Association, *Korea and the World Key Indicators 1994*, p23.

7 * Statistics Office, *Korea through the Statistics*, 1995, p315.

8 * Statistics Office, *Korea through the Statistics*, 1995, pp 500-507.

9 Ministry of the Environment, *National Report of the Republic of Korea to UNCED 1992*, p 48.

10 Ministry of the Environment, *National Report of the Republic of Korea to UNCED 1992*, pp 50-51.

11 * Ministry of the Environment, *Environment White Paper 1995*, p35.

12 * Ministry of the Environment, *Environment White Paper 1992*, p118.

13 * Ministry of the Environment, *Environment White Paper 1995*, pp 111-112.

14 * Ministry of the Environment, *Environment White Paper 1992*, pp 177-178.

15 * Ministry of the Environment, *Environment White Paper 1995*, pp 193-194.

16 Korea Foreign Trade Association, *Korea and the World Key Indicators*, 1994, p22.

17 Ministry of the Environment, *National Report of the Republic of Korea to UNCED 1992*, December 1991, pp 54-56.

18 * Ministry of the Environment, *Environment White Paper 1992*, p 349, and Ministry of Environment, *Environment White Paper 1995*, p 411.

19 Ministry of the Environment, Republic of Korea, *National Report of the Republic of Korea to UNCED 1992*, December 1991, pp 90-91.

20 * Ministry of the Environment, *Environment White Paper 1992*, pp 349-350.

21 * Korean Church Environment Research Institute, *Newspaper Environment Materials About Peace and the Environment in 1992*, February 1993.

22 * Ministry of the Environment, *Environment White Paper 1995*, pp 404-405.

23 * Ministry of the Environment, *Environment White Paper 1995*, pp 406-407.

24 Ministry of the Environment, *Environmental Protection in Korea 1993*, p2.

25 Ministry of the Environment, Republic of Korea, *National Report of the Republic of Korea to UNCED 1992*, December 1991, pp 71-72.

26 Ministry of the Environment, *Environmental Protection in Korea* , 1993, p3.

27 * Ministry of the Environment, *Environment White Paper 1995*, pp 498-499 &

Ministry of the Environment, *Environmental Protection in Korea*, 1993, pp 4-5.

28 Ministry of the Environment, *Environmental Protection in Korea 1993*, pp 20-21.

29 * Ministry of the Environment, *Environment White Paper 1995*, p 454.

30 * Ministry of the Environment, *Environment White Paper 1995*, pp 458-460.

31 See Figure 2-11 for details

32 * Ministry of the Environment, *International Environment Tendency and our Response after UNCED, June 1993*, pp 5-6

33 * Ministry of the Environment, *Environment White Paper 1995*, pp 479-481

Chapter 3.

Housing and High-rise Apartments in Korea

The concept of housing in Korea has changed because of the rapid economic development since the 1960s. After difficult conditions in the first half of the twentieth century, Korea entered a rapid growth generation. Lifestyles have changed from calm rural life to vigorous city life, as mentioned in the previous chapter. Young people, especially, have moved to the urban areas in which a quite different lifestyle awaits them. They no longer live at home, so the attachment to their home is not as strong as it was for previous generations.

Because of enormous population growth and urban concentration, the shortage of housing units has become one of the major social problems in big cities. Moreover, the size of family units has become smaller, requiring even more housing units. Successful economic growth itself could not solve the housing problem without a special policy for massive production of housing units. In this context, massive production methods and how to efficiently provide people with homes, have been investigated.

The first section of this chapter seeks to define housing and high-rise residential buildings in general terms. The terminology of residential building in the Korean context is followed, focusing on the definitions of some words, which have different meanings depending on the country.

The second section of this chapter looks at the regulations which are related to apartment developments in Korea. Starting from social and economic elements for apartment developments, this section summarises architecture law and environmental policy which is related to apartment construction.

The third section of this chapter is a history of apartment buildings in Korea, which started to appear in the late 1950s. This section searches for trends in apartment construction, with reference to housing requirements in Korea. Through the history of the rapid economic growth period, the housing requirements in big cities have never stopped growing in spite of efforts to produce many housing units. This massive housing construction has brought about a new concept of the home. The distinctive features of each decade are described step by step, with some references to social changes.

The fourth section of this chapter analyses apartments in recently established new towns. Five new town developments around Seoul are the latest efforts to solve the housing problems in the capital region. Current trends in these five new town developments are described to investigate recent apartment development. Among the five, Pundang is examined thoroughly. After describing the masterplan of Pundang, apartment developments in Pundang are assessed. Apartment construction in Pundang is representative of Korea's current apartment construction industry.

Finally, the last section of this chapter deals with the problems of current housing developments in Korea.

3-1. Characteristics of Residential Buildings

3-1-1. Housing and Dwelling

Buildings, in general, separate their occupants from hostile external environments and create a better internal environment for their occupants. Therefore, buildings can be likened to an extension of our bodies as the third skin, next to the body as the first skin and clothes as the second skin. Besides this role, the housing objectives have more complex patterns than other buildings, because everyone has differentiated functions in their daily life, starting from and finishing in their homes. People come back from a system of interactions on shared values to their homes regularly to recover their personal identity and to have a rest from their routine tasks. Therefore, designing houses involves not only designing a building, but also providing people with comfortable, security and peaceful space for their own identities.

Housing forms have changed in a specific geographical context throughout the history. Different housing forms are provided to serve the same or similar domestic functions in the same or different societies, and there are individual differences within a general cultural pattern.[1] It is complicated to design houses or other types of housing units, because they always include many different elements. When architects design houses, they must not just show what is possible. They must also, and especially, show what should be possible for everyone. Social or sociocultural factors such as economy, household structure, religious practices and collective spatial images should also be considered for housing design, not solely physical elements such as materials, technology, site and climate.

The word dwelling, as a place of residence, means something more than having a roof over our head and a certain number of square metres at our disposal. First, it means to meet others for an exchange of products, ideas and feelings, that is, to experience life as a multitude of possibilities. Second, it means to come to an agreement with others, that is, to accept a set of common values. Finally, it means to be oneself, in the sense of having a small chosen world of our own. The word dwelling, however, also comprises the places man has created to set the modes into his work. To dwell implies the establishment of a meaningful relationship between human beings and a given environment. Man, thus, finds himself when he settles, and his being-in-the-world is thereby determined.

3-1-2. High-rise Residential Buildings

Modern industrial society makes people move from rural areas to cities, necessitating a large amount of housing units built in a short time, especially during periods of economic growth. This situation has resulted in large cities having a lot of high density dwellings in the shape of high-rise buildings. A common system of housing production in this context is the system which produces public apartment houses. In this system, apartments are built for the government by developers, either private or government controlled. The individual dwellings are identical cells arranged in several stories of apartment buildings. It is taken for granted that the apartments will later be rented or purchased by families who have nothing to do with the process of their production. It is very difficult to satisfy all families who will occupy apartment units, but designers should, at least, keep in mind that there are many different requirements from different families.

The system of housing production is a coherent system. It is not designed by any one person or group of people. But it is, nevertheless, a system - a system of rules, habits, laws, and accepted procedures, taken for granted throughout society, and responsible for the production of most of the houses in society. What we should look for is a social process which brings people together in new relationships and patterns of living, in other words, a continual community building process where individuals and groups develop by giving each other support and stimulation as they work to design their immediate environment and take responsibility for its maintenance and future development. In the systems of housing production nowadays, it is found that almost all of them lack two necessities fundamental to any human society; firstly, recognition of the fact that every family, and every person, is unique, and must be able to express that uniqueness and secondly, recognition of the fact that every family, and every person, is part of society and requires bonds of association with other people. These two fundamental necessities are very important in the case of mass production with multiples of the same floor plan in apartment buildings. As a cooperation of housing units, an apartment building should have more meaning besides the role of dwelling.

People living in an apartment building have both private spaces for their own family and public spaces for sharing with other families. Even once a resident has purchased one unit, the public spaces cannot be his own. Furthermore, water pipes, heating systems and gas pipes cannot be changed or repaired by a single unit.

Throughout the world, the number of apartment buildings has increased particularly since the Second World War. In the developing countries, housing shortage and modernisation have both accelerated the speed of apartment construction. Korea is a typical example of this global trend. After starting the first 5-year economic development plan in 1962, people in Korea became familiar with modern urban life. Life in an apartment building is one factor in these new lifestyles.

3-1-3. Terminology of Residential Building in the Korean Context

In different circumstances with a different cultural base, the same word can be used with a different meaning, or different words can be used with the same meaning. The definition of words for a certain environment, therefore, is important. The definition of a *house* in Korea has a complex meaning: when we say a *house* in Korea, this usually includes all types of dwellings. However, a *house* may also be defined as a detached house, and *housing* used for all types of dwelling buildings. Most houses are detached houses, and if they share something, even a wall, in the house, this type of housing is called *cooperative housing*, and an *apartment* is one of three types of cooperative housing. The others are an *attached house* and a *multi-family house*, which are usually called a tenement or terraced house in Britain. A multi-family house has recently been defined as 'a housing building for a few housing units'. The classification of housing types as outlined in the Architecture Law (building regulation) is shown in Figure 3-1.

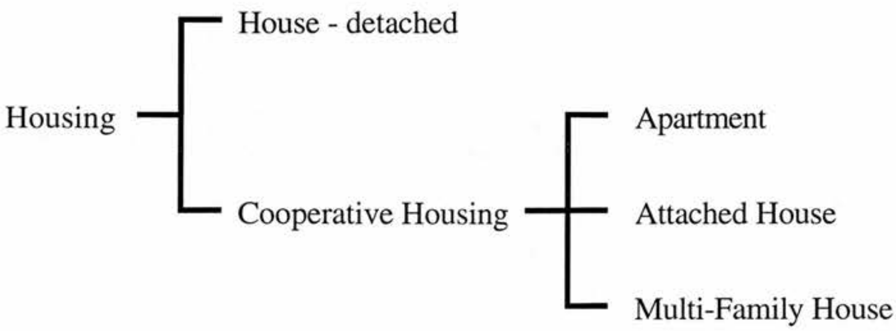


Figure 3-1. Housing Types in the Korean Context

According to the definition in the Architecture Law (Building Regulation), an apartment building is a housing building with five or more storeys. An attached house is a housing building with four or less storeys, total floor area of which exceeds 660 square metres, and multi-family housing is a building with four or less storeys and the total floor area is 660 square metres or less.[2] Most houses are detached houses, which have their separate buildings and gardens within their own boundaries. However, in some cases, two or more families are sharing one detached house, since there are not sufficient housing units. Unlike in Britain, in Korea it is unusual to have a semi-detached house.

For apartment buildings, the definition of *high-rise* differs between countries. In some countries this word means a building with just around 5 or 10 storeys, while in other countries it stands for over 20 or 30 storeys high. In this thesis, the term high-rise is applied to an apartment which has lift facilities[3]. Apartment buildings between six and nine storeys high are hardly found in Korea, so high-rise apartment buildings usually mean more than ten storey buildings. Recent high-rise apartments tend to be over 15 storeys and some of them reach 30 storeys. Some six-storey apartment buildings built before 1980 do not have lifts, so they are categorised as low-rise apartments.

Apartment buildings in Korea usually form a group, not standing as a single tower block. A group of apartment buildings is defined as an *estate*, while the term *apartment building* is used for a tower block or an apartment block. Land is always required in order to construct buildings. A land area for apartments divided by public roads is defined as a *land block*. Usually a land block is the same as an apartment estate, but sometimes a land block is divided into a few apartment estates.

In Korea, the most widely used area measurement for an apartment or house unit is PY(pyeong). 1 PY is about 3.3 square metre. People easily understand the area shown by PY, even though square metres are used for most governmental regulations. Unlike in Britain, where housing units are categorised as one-, two- or three-bedroom houses or flats, area shown by PY or square metres is most widely used for the size of an apartment in Korea.

3-2. Regulations related to High-rise Apartment Development

3-2-1. Social and Economic Elements for Apartments

Since available land area is small compared to the population, the price of land is a pressure element for housing construction. Population density in Seoul is about 18,000 persons/km^2 (180 persons/ha) and that of some dense residential areas is over 500 persons/ha, so finding suitable areas for housing in Seoul is difficult. For this reason, urban areas have expanded on the outskirts of Seoul. Yet even in these suburban areas, it is difficult to have low-density dwelling developments. The target population density of Pundang, as a new town locating suburb of Seoul, is more than 200 person/ha.

In this unpleasant situation, people need more open space with green plants in the area of their own apartment estates, as well as public parks. However, this open space resulting from high-rise development cannot be used for a single purpose, due to the struggle between social requirement and environmental requirements. Open areas are, therefore, divided into public or shopping centres, car parking areas, sports facilities and green spaces.

Traditionally Korean people have had a strong attachment to the land. After a republican government was established in 1945, the further idea of land as a symbol of wealth was introduced by the free market economy. Industrial bodies accumulated more land than they needed, and families were very eager to have their own land. Therefore, the price of land has gone up much more sharply than GNP, or other market price. The price of real estate has also gone up, in accordance with the land price, especially in the 1980s.

Land prices in urban areas, which have a great impact on housing prices, are very high, because of massive migration from rural to urban areas. Shortage of housing units adds to the sharp increase in housing prices. The main issue for the Government then has been to provide very large number of housing units within a short period. Eagerness to own a home rather than rent has helped the Government and construction companies to provide massive housing units for sale. The massive increase in housing prices, including that of apartments, has threatened other market prices. The requirement of housing units has caused a serious problem since the early 1980s, along with the price problem. Although people have faced the problem of not having their own home due to their salaries, the trend to buy homes has not been stopped. This is a delight for construction companies, because they do not need to worry about how to sell housing units.

Food is not an issue with rapid economic growth, though it was a major problem less than a half century ago. The main concern for people now is the quality of their life. They require enough space and good facilities for their own home, and eagerness for a better environment in and around their home has increased. The requirement for bigger units has increased for families who already have their own home, whilst a lot of families still cannot afford to have their own homes. Therefore, when developing and constructing new housing buildings, the variety of housing unit size on offer should be considered. Massive construction of housing units seems to be continued for the target of housing spread rate[4] suggested by the Government. Although the increase in population has become steady at around one percent per year, the increase of family numbers is expected to remain high because of the change in family organisation.

The Government have controlled the price of new apartment units for the people who wanted to have their own homes. Hence, the price of a new apartment unit is much less than that of an existing one, providing the least margin of profits for construction companies. The Government controls the size of each unit as well. Construction companies should provide a certain percentage of small size units for poor people, even though they prefer to build bigger ones. Construction companies can get a better profit through bigger units, and they do not need to worry about selling them because the demand for apartment units has been very high, especially in and around big cities. Even though the construction companies are not satisfied with governmental policy, they do not complain much because massive production can give them certain profits even under these circumstances.

3-2-2. Architecture Regulations

There are various regulations (laws) for buildings or architectural design in Korea, of which Architecture Law (Building Regulation) is the main and most important one. Apart from this, the Car Parking Place Law, the Urban Planning Law, and the Housing Construction Stimulation Law are those related to apartment construction. The Housing Construction Stimulation Law is especially made for providing and managing houses and apartments.

Architecture Law includes the definition of buildings, construction of buildings, permission or report of building construction, maintenance and management, special purpose building, criteria of service facilities, etc. All buildings including houses and apartments should follow the rules. Some regulations applied to apartment buildings are for a better internal, regional or global environment. For example, the height of each building is restricted according to the distance to adjacent buildings. All units in apartment buildings should receive a certain amount of sunshine, and this is decided by a regional regulation. Mostly, they should have access to four hours of sunshine in winter (the winter solstice) between 9 am and 3 pm. (Regulation 53, Ordinance 86)

Proper heating systems are required as well. All apartment buildings which are six or more storeys, are recommended to have central (or district) heating systems. If individual heating systems are used, some regulations for safety and energy efficiency should be met. (Ordinance 86) As a heating mode for each unit, most apartments use an underground heating system. When such a system is used, the structure and materials used follow the regulations, which will be described in a later part of this chapter. For energy efficiency, thermal transmittance of building envelopes are also guided by the Law, which will also be presented later. An apartment building, which has more than fifty units and (a) central heating system(s), should be prepared to submit an energy saving plan. (Regulation 59) One lift is required in every 3,000 square metres of six and higher storey buildings. (Regulation 57, Ordinance 89)

Regulations for energy saving for building appeared at the end of 1975 in Architecture Law (building regulation), and heat loss prevention for buildings was created in 1976. In 1984, the country was divided into two zones to have an efficient criteria in each zone according to the weather condition, and the zones were amended to three in 1987. An energy saving plan for big buildings has been recommended since 1985, and a guide for making a plan was launched in 1991. Submitting an energy saving plan for big buildings became compulsory in 1992. The plan should be submitted to a regional council.[5] For apartments, an estate with a central heating facility and having more than 50 housing units should submit an energy saving plan. When an energy saving plan is submitted, heating and cooling load and insulation criteria should be met to the building regulations according to regional variations. For preventing heat loss, there are criteria of thermal performance for building skins concerning thermal transfer rates and the depth of insulation, according to the region.[6]

Housing Construction Promotion Law has been applied to housing buildings including houses and apartments since 1977. The definition of an apartment and other types of housing buildings are shown in the first part of this law. Apart from the definition of terms, funds for housing, development of apartment districts, construction and supply of housing units, apartment management, building materials, new technical supported housing types, housing associations, etc. are shown in the Law.

The government founded the 'Kukmin Housing Fund' for efficient production and provision of housing units. (Regulation 10) The money is used for the construction of small-sized housing (Kukmin Housing), mortgage for families purchasing Kukmin Housing, housing research and development, and so on. The funds are collected by central and regional governments, borrowing from other associations and from overseas. Kukmin Housing is defined by size: houses or apartment units which have an area of 85 square metres or less.

Apartment district developments, for large scale construction, are defined by the Law. (Regulation 20) Development can be done generally by the Government, Regional Government, Korea National Housing Corporation (KNHC), Korea Land Development Corporation (KLDC) or Regional Land Development Corporations. Exceptions occur when no application has been taken up one year after a public notice; when no development is commenced six months after an application for the development; when the development has special requirements because of natural disasters etc. (Regulation 21) In these cases, large-scale private construction companies, which have been designated by the Government, can take over the responsibility. Companies of superiority in finance and technology only can be designated. (Regulation 8)

Management of apartment buildings is also included in this Law. Construction companies have a responsibility for a certain period for the management until the committee of residents decide a management type. Apart from this responsibility, construction companies should maintain the structure for an appointed period. (Regulation 38) Details are described in a later part of this chapter.

3-2-3. Environmental Policy Applied to Apartments

The environmental regulations have been specialised since 1990. Until July 1990, all regulations about the environment were within one law. This was divided into six laws in August 1990, and the number of laws governed by the Ministry of Environment increased to eighteen in 1994. These are;

1. the Environmental Policy Regulation,
2. the Regulation for mediating Environmental Dispute,
3. the Air Preservation Regulation,
4. the Water Preservation Regulation,
5. the Regulation for Noise and Vibration,
6. the Regulation for Harmful Chemical Material Management,
7. the Regulation for Ocean Pollution Prevention,
8. the Regulation for Waste Management,
9. the Regulation for Saving Natural Resources and Promotion of Recycling,
10. the Regulation for International Trade of Wastes and its Handling,
11. the Regulation for Sewage Treatment,
12. the Natural Environment Conservation Regulation,
13. the Regulation for bearing the Environment Improvement Expense (established 31 December 1991),
14. the Regulation for Environmental Effect Estimation,
15. Regulations of Special Finance for Improving the Environment (established 5 January 1994),
16. the Special Regulation for Penalties against Environmental Crime (established 31 May 1991),
17. the Regulation for Recycling Used Materials (established 27 December 1993),
18. the Environmental Management Cooperation Regulation.

In addition to these, laws such as the Regulation for International Cooperation preventing Ozone Layer Depletion are also important for the environment.

Governmental environment policy nowadays concentrates on the regional pollution of air and water. Urban traffic systems and water quality of rivers are the major concerns of government policy. Issues concerning buildings are mainly for indoor air pollution levels for offices, factories and department stores which many people use together. Since the population's main concern has shifted from economic problems to environmental problems after the late 1980s, concern for environmental problems in urban areas has increased. Government policy has reflected people's concern for reducing pollution levels in the urban community. This has made enormous improvements in the pollution levels in big cities, as described in chapter 2. However, it is still a new idea to be concerned about the sustainable development of the construction industry, even though the construction industry has a big impact on the environment.

Most regulations, however, apply to the construction industry, which uses massive amounts of raw materials, and which, along with manufacturing industries for building materials and the construction process, produces pollutants which degrade the air, water and the earth. The biggest issue for an apartment building is to reduce energy consumption while the building is used. The main reason for this issue is not only for the protection of the environment, but also for financial reasons. Energy security also plays an important role in this topic, because most energy is imported rather than coming from domestic production. Noise problems between units, indoor air quality and open green space with good air quality are followed as issues by the energy problem. Most of these concerns are related to global environmental issues such as global warming and ozone depletion, but people's recognition of the construction industry as related to the global environment is not yet well established in Korea. Public opinion focuses on the responsibility of manufacturing industries such as steel, ship and car production, and transportation.

3-3. History of Apartment Development with References to Social Changes

3-3-1 Commencing Stage of Apartment Construction in the 1960s

Apartment construction started in the late 1950s by construction companies operated by the Government. The number of apartments constructed in Korea before 1960 was altogether 363 housing units: 136 units constructed in 1957, 152 in 1958, and 75 in 1959. [7] They were all in Seoul. These apartment units did not sell well, and most of the units were occupied by the employees of the construction company. However, the government continued to build apartments to provide people with a new modern housing option. Apartments certainly improved sanitation conditions, water supply, and other facilities in city life, even though it took a considerable length of time to draw people's attention to these advantages.

The starting point of apartment construction in Korea, however, can be traced back to December 1962, when the Mapo Apartment in Seoul was completed.[8] After the Korean War, the government in Korea was unstable for a while. When a military regime took over the political power in 1961, the government formulated a new five-year Economic Development Plan which started from 1962. This became one of the driving forces of subsequent economic growth. Continuous five-year Economic Development Plans followed and the eighth five-year plan is still in progress (1997 - 2002), although the name changed to Economic and Social Development Plan from the Fifth Plan (1982 - 1986).[9] The Government focused on economic development to overcome the poor conditions of the 1960s. During this process, Korea has moved into being an industrial country with a concentration of population in urban areas. Slum areas have appeared in most suburban areas of major cities because poor people were attracted to come to the urban areas, despite their lack of economic ability to achieve a basic living standard. The idea of building apartments was conceived in this context the aim being to provide proper dwelling for the people in slum areas. The Mapo

Apartment was one of the major targets of the housing plan for the First Economic Development Plan.

The Mapo Apartment was originally planned to be ten storeys high with lift facilities and central heating systems. The purpose of this apartment estate was not only for residents but also as an advertisement to the people in and out of the country to show that the Government had the technological ability to make high-rise buildings.[10] Public opinion, however, prevented the planners from making such a lavish design since Korea lacked electricity for running a lift and gasoline (oil) for central heating. Therefore a group of six-storey apartment buildings with 450 units was completed by the first of December 1962.

These apartments did not sell well at first because six-storey buildings were too high for the people of that period. Another difficulty was that the Mapo Apartment estate had some defective water pipes, which froze and then burst because the estate was completed in the winter and some units remained unsold through the winter. It was inevitable that without using the pipes, in temperatures of an average of below freezing point in January, the water in the pipes would freeze and burst. Only one tenth of the apartments were initially sold, the remainder not being sold until the following year. Despite these bad selling conditions, 642 additional housing units were built on the Mapo Apartment Estate over the following three years.

In the first half of the 1960s, small-sized apartments were mostly constructed in the Seoul metropolitan area, including the Mapo Estate. In addition to building in the capital area, the trends of apartment construction spread to big regional cities. Apartments for public officials[11] started to be built in five big cities in 1966, including Seoul itself. They are all low-rise estates with a few apartment units.

The first high rise apartment estate was built in Seoul in 1967,[12] and was intended for the foreign people living in Seoul. It symbolised the start of a changing skyline in Seoul. This high rise apartment was, however, exceptional at this time, as the height of most apartments in the 1960s was five storeys or less, which did not require lift facilities. Safety and power security had priority over the land use at that time.

Population concentration in the Seoul metropolitan area was accelerated as economic development became one of the Government's major issues. Slum areas spread rapidly around the central, economic areas. In order to clear the slums, about 20,000 small apartment units around 11 PY[13] (36.3 m^2) were built in various areas by the end of the 1960s. These small size apartments are called citizen housing[14], and the government has given special incentives on mortgages and taxes.

Apartments were not, however, attractive at that time. Most apartment buildings were constructed not because of the requirement of the residents, but for the clearance of slum areas. Therefore, the unit size was small and apartments were recognised as an inferior housing type. People regarded an apartment as a temporary dwelling rather than their own home.

3-3-2. Appearance of High-rise Apartments and Massive Construction in the 1970s

By the end of the 1960s, the Government and construction companies tried to build apartments mainly for the poor, and the only thing they were concerned with was to provide home for these people in a short time, while clearing slum areas. This rapid construction caused fraudulent work, and eventually led to a major accident in the early 1970s. An apartment called Wawoo collapsed and 33 people were killed in April 1970.[15] After the accident, apartments in Korea were built more carefully, and tended to become luxurious for the middle and upper class people rather than the poor. They tried to place importance on advanced safety technology rather than costs. These efforts required additional finance, so the target market for these apartments became richer people.

The first estate of apartments for the upper classes was built in 1971 in Yoido island[16] having 1584 housing units with 12 storeys and central heating facilities. The area of Jamsil where the Seoul Olympic Stadium is located, had changed from a plain field to an apartment forest in 1975. These apartments are much bigger than before, in both the estate size and the unit size. Construction companies, competing with each other, tried to focus on the merits of living in an apartment. Modern city life, with convenient access to other places such as markets and leisure facilities and proper traffic networks, were emphasised and this attracted rich people. Some apartments constructed in the late 1970s had a competitive rate over one per hundred, which means one hundred buyers for each flat.[17] The apartments, then, became speculative commodities, causing an enormous increase of apartment prices. Starting with Jamsil, price climbing moved to the apartments in Yoido, which were built earlier than those in Jamsil. Until a certain time, the demand for housing units was great but the demand for apartments was small, so it is little wonder that the Government did not prevent apartment buildings from becoming speculative goods. Thus, apartment buildings gradually became attractive to many people, and the enormous increase in apartment prices continued for around twenty years.

The main companies constructing apartments up to the mid-1970s were public companies, namely the Korea National Housing Corporation (KNHC) and Seoul City Operated Housing Company (or other city operated housing companies), but from the late 1970s, their monopoly finished and private companies began to play a leading role. Before they became competitive in apartment construction, private companies had built houses or infrastructures. Using these construction experiences, each company developed their own individual style of apartments. This trend has made Korean apartments even more luxurious and more fashionable, with rich people becoming increasing interested in them. The size of estates also became bigger, and some estates have more than 50 apartment buildings. In some places, many estates were located adjacent to each other. Apartment estates gradually replaced natural villages in many areas, changing people's lifestyles.

The number of apartments built in this period is, however, just half that of houses. The number of housing units constructed had steadily increased year by year, but the speed of the increase in households was much more rapid than that of the increase in housing units. One reason for the rapid increase in the number of households was population increase, but a more important factor was the reduction in household unit size. The average number of people per households decreased from 5.2 in 1970 to 4.5 in 1980.[18] Therefore despite the steady construction of housing units, housing spread rate decreased throughout the 1970s.

3-3-3. New Generation of Apartment Construction from the 1980s

Even with remarkable economic growth, the problem of housing in Korea has never ceased to exist. The amount of housing required has increased along with the desire for higher standard of living. The number of family units increased by 370,000 per year between 1980 and 1987, but housing units built at the same period amounted to only 220,000 per year. The lack of 150,000 housing units per year, therefore, has resulted in a decrease in housing spread rate from 72.7% in 1980, to 69.2% in 1987.[19]

In 1987, The Government announced a major project to build two million housing units between 1988 and 1992.[20] This figure shows that 400,000 housing units had to be built every year during this period. The average number of housing construction per year between 1982 and 1987 was about 230,000,[21] so the figure for two million housing units seemed to be an ideal. However, thanks to some political pressure, two million housing units were indeed completed within four years.

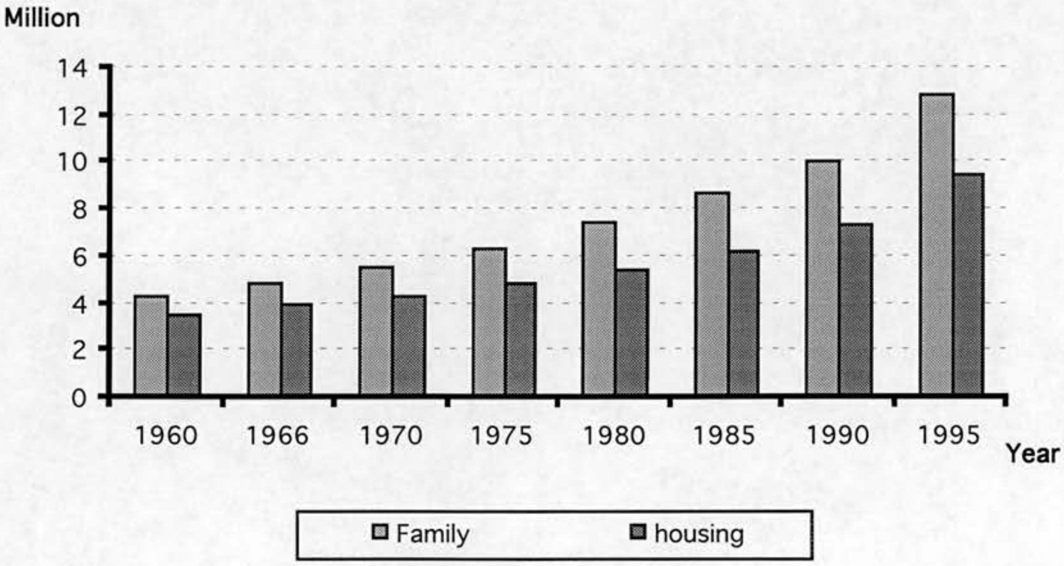
One of the reasons that the two million housing construction plan was accomplished, was the five new town plans around Seoul. In April 1989, the government announced a surprisingly ambitious plan - the five new town development plan. Around Seoul City, it was decided to build five new towns, mainly to provide people with homes. To investigate current apartment construction in Korea, it is necessary to look at the five new town plan, and the details of this plan are described in the next section. The plan implied two positive things: one was to accomplished 'the Two Million Housing Construction Plan', and the other was the decentralisation of the Seoul population. Fast construction of big cities produces negative effects as well, such as extension of the metropolitan urban area and traffic problems in capital regions.

Other than the housing problem at the national level, the problem in and around the Seoul metropolitan area is a separate issue. Population concentration had never faded and finally the population in Seoul reached ten million in 1989 while that in 1960 was just 2.4 million.[22] Suburban open spaces had been transformed by huge apartment buildings by the middle 1980s, and there was a lack of big open spaces for massive housing construction in Seoul. Since Korea hosted two major sports events - the Asian Sports Games in 1986 and the Olympic Games in 1988 - both in Seoul, government financial support for the construction industry concentrated on building the Olympic Complex.

By the late 1980s, the number of apartments in Seoul grew to around 600 thousand, of which the number of apartments in Kangnam-gu[23] and Kangdong-gu was around 250 thousand, making up 45% of all apartments in Seoul. In these areas, 90% of housing is apartments, turning these areas into apartment jungles. Even with this huge number of apartments, many more apartment units are still needed. The demand for new apartments is usually 10-20 times more than the apartments on offer, and hence the Government has to have a policy to provide many new apartment units. The provision of luxury apartments in Seoul, however, has reduced since May 1987 after the Olympic Family Apartment was provided.[24] Nearly the last big apartment estates were those in the Seoul Olympic Complex, originally built for the Olympic teams, then sold to Seoul citizens. This is why space for housing outside Seoul is now required.

3-3-4. Summary of Apartment Construction History

The number of existing housing units in 1960 was 2.59 million, while the number of family units was 4.26 million. Through the baby booms and industrialisation after the Korean War, the number of families in 1990 was more than 10 million, reaching 12.9 million in 1995. The number of family units, therefore, became three times more in 1995 than in 1960, while the population increased by less than double in the same period, from 25 million in 1960 to 44.85 million in 1995.[25] The number of housing units has always been less than that of family units. The trends of family units and housing units are shown in Figure 3-2.



Figurte 3-2. Trends of Family and Housing Numbers

Source : KNHC, **Housing Statistic Year Book,** 1994, p 183.
& Daily Newpaper, **Korea Herald**, 31 March 1996.

Family size has been reduced through birth control and the separation of young families from older generations. Therefore, each family has less people than before, requiring more housing units and different housing types. The average family size decreased from 5.2 in 1970 to 3.4 in 1995. The trend of family size is shown in Figure 3-3.

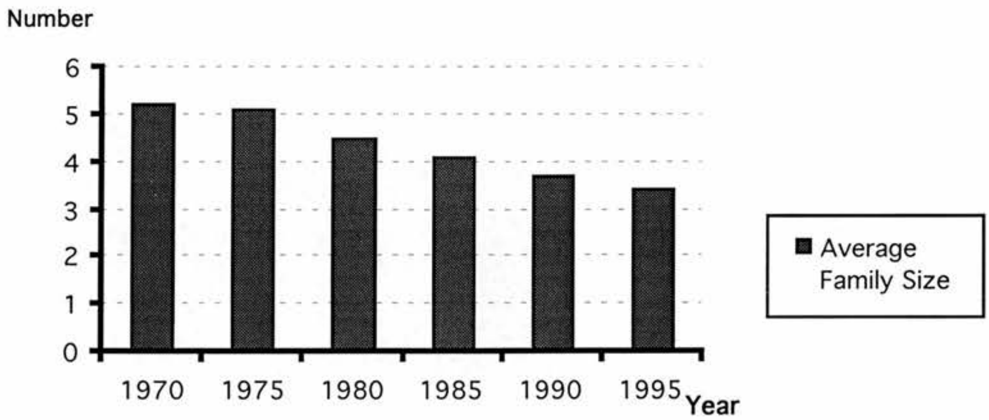


Figure 3-3. Trends of Average Family Size

Source : KNHC, **Housing Statistic Yearbook,** 1994, p99.
& Daily Newspaper, **Korea Herald,** 31 March 1996.

The number of housing units built since the 1960s has changed dramatically. The number of housing units being constructed between 1962 and 1971 was about 866 thousand. This means that only about 86 thousand housing units were built each year in this period. From the late 1970s, the number of housing units built each year was more than 200 thousand, and this trend continued until the late 1980s, although the demand for housing units was much greater in the 1980s than before. The number of housing units constructed each year between 1980 and 1987 was even less than in 1978, which caused a serious housing unit shortage in the late 1980s.[26]

However, due to Governmental efforts to solve the housing problem, housing construction has exceeded the increase in households since 1987. The amount of housing construction changed considerably from 1989, when apartments in five new towns started to be constructed. This trend will continue until the end of this century when these new towns will be completed. The Government has a plan for more new towns after finishing construction of apartments and other types of housing in these five new towns. Most housing units in these new towns are apartment buildings. The number of apartment units has changed dramatically, while that of other housing units has stayed nearly the same since the 1970s. This trend is shown in Figure 3-4.

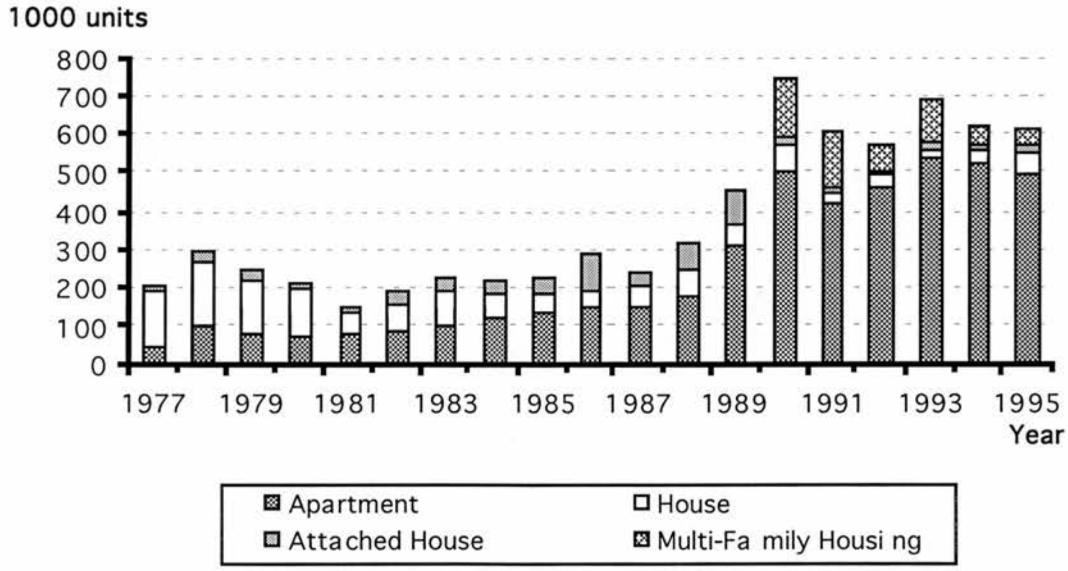


Figure 3-4. Trends of the Number of Housing Units Constructed

Source: KNHC, **Housing Statistic Year Book**, 1994, p258
& Daily Newspaper, **Chosun Ilbo**, 2, February, 1996

Thanks to massive construction projects from the late 1980s, housing spread rate started to increase from 1987. However, housing spread rate in 1995 was still below 85 percent, which is nearly the same as that in 1960. The Government has a plan to achieve the figure of 92.8 percent by 2001 and 100 percent by 2010. The trend of housing spread rate is shown in Figure 3-5.

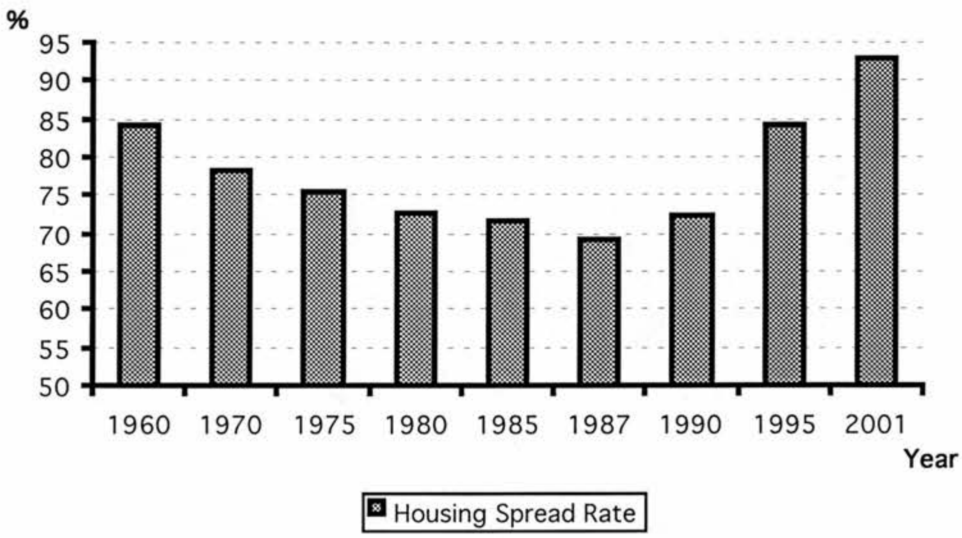


Figure 3-5. Trends of Housing Spread Rate

Source : KNHC, **Housing Statistic Year Book**,1994 p183 & Daily Newspaper, **Joongang Ilbo**, 10 March 1996.

The apartment construction in these new towns is representative of current national high-rise apartment construction. Therefore, in order to examine the current apartment construction industry in more detail, Pundang New Town and its apartments will be analysed.

3-4. New Town Development and Apartment Construction

3-4-1. The Five New Town Development Plan

The problem of housing unit shortage in the Seoul metropolitan area has not been eased since the 1960s. This has been aggravated by the fact that there is insufficient land space in Seoul for further mass housing estates. To solve the continuous housing shortage crisis in Seoul, the Five New Town Plan was announced in April 1989. The main purpose of these new towns are to disperse the Seoul population. The five new towns are all around 20 to 25 kilometres from Seoul. The location of these five new towns and their distance from Seoul is shown in Figure 3-6.

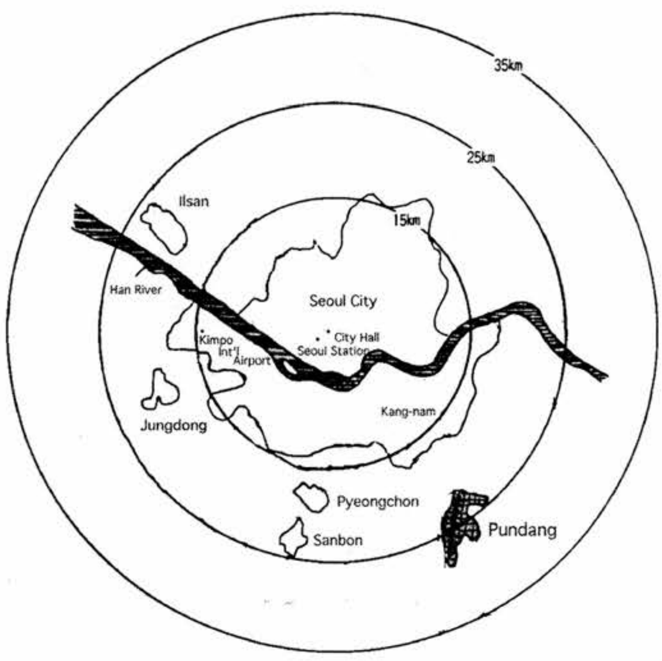


Figure 3-6. Location of the Five New Towns around Seoul

The master plans of the five new towns are quite similar to one another. Wide lattice type road systems with big land blocks are typical, although there are some variations according to the natural environment, such as rivers, mountains, etc. This similarity is mainly due to the housing composition. High-rise apartments need a big land block and high density needs wide roads with a flowing traffic system - that is lattice type.[27] Even though these new towns lack traditional community areas, they are very convenient and tidy modern cities. Like other new towns in the world, housing is the dominant plan in these five new towns. Some 293 thousand housing units are being built in these new towns. Among them, some 270 thousand housing units are apartments, occupying 92 per cent of the total housing stock, and most of them are high-rise. The master plan of the five new towns, focusing on the housing construction and population placement, is shown in Table 3-1.

Table 3-1. Master Plan of the Five New Towns around Seoul

	Pundang (Seongnam)	Ilsan (Koyang)	Pyeongchon (Anyang)	Sanbon (Kunpo)	Jungdong (Puchon)	Total
Distance from Seoul (km)	25	20	20	24	20	
Area (km^2)	18.89	15.73	4.95	4.26	5.44	49.27
Target Population (1000 people)	390	276	170	170	170	1,176
Number of Households (1000 units)	97.0	69.0	42.5	42.5	42.5	293.5
Population density (person /ha)	213	175	344	406	313	
Average House size (PY)	30	29	27	24	26	
Average House size (m^2)	99	95.7	89.1	79.2	85.8	

Source : Ministry of Construction, the Government of Korea

The geographical centre of each planned town is the office and commercial area, including shopping centres. The surrounding parts of this small office and commercial area are residential areas with some parks, regional shopping centres, leisure centres and connecting roads. Each new town is linked to Seoul by underground (subway) systems, highways (motorway) and other local roads. Many Seoul city buses are extending their services to these new towns, competing with the city bus within the new towns. Most of the regional bus services connect underground stations and residential areas.

3-4-2. Pundang New Town

The chosen new town, Pundang, is the biggest of the five. The construction of apartment buildings is still going on in the middle of the 1990s, with many more types of building such as offices, department stores, stations etc.

Pundang is located south-east of Seoul. The distance between Pundang and the city centre of Seoul is about 25 *km* and between Kangnam, which is the secondary centre of Seoul, only 10 *km*. Kangnam is a recently developed area with plenty of luxury apartments.[28] Pundang new town was aimed at the people who lived in the Kangnam area. It takes only 30 minutes from Pundang to the Kangnam area by underground, and less than an hour to the city centre. Concerning the distance, the commuters between Pundang and Seoul can be assumed up to 80% of all working people.[29] Therefore, Pundang New Town may be considered just an expansion of the existing big city, Seoul. Kangnam Province in Seoul developed in the same way when the city expanded from the old city area near the city hall and Seoul station in the 1970s.

The urban master plan for Pundang commenced in 1989 with four other new town plans, and construction started within a year. The master plan of Pundang was designed by Korea Land Development Cooperation (KLDC). Besides dispersing Seoul populations, Pundang has three other aims to make the city: 1. more pleasant and abundant; 2. more convenient; 3. safer.[30] For a more pleasant and abundant city, preservation of historic sites and harmony with nature are focused on. Ample green parks with traditional monuments are located throughout the new town. To make the city more convenient, efficient traffic systems with underground, public bus routes, and highway roads, connect Seoul and Pundang. Local traffic is organised around the underground stations. Regional, commercial and leisure facilities are arranged for the residents. Road traffic safety is also important, and designers tried to separate pedestrians from automobiles, in order to prevent road accidents.

Pundang has a long north - south axis. To the north of the planned site is a green belt area and to the west is a motorway. In the south-east is steep land, while a military base occupies the north-east and an airfield is in the north-west. The natural environment makes the area of Pundang an unusual shape.[31] The development started from the central part of Pundang, and then from the north, which is near to Seoul, to the south. Development stages of Pundang new town with surrounding areas of are shown in Figure 3-7.

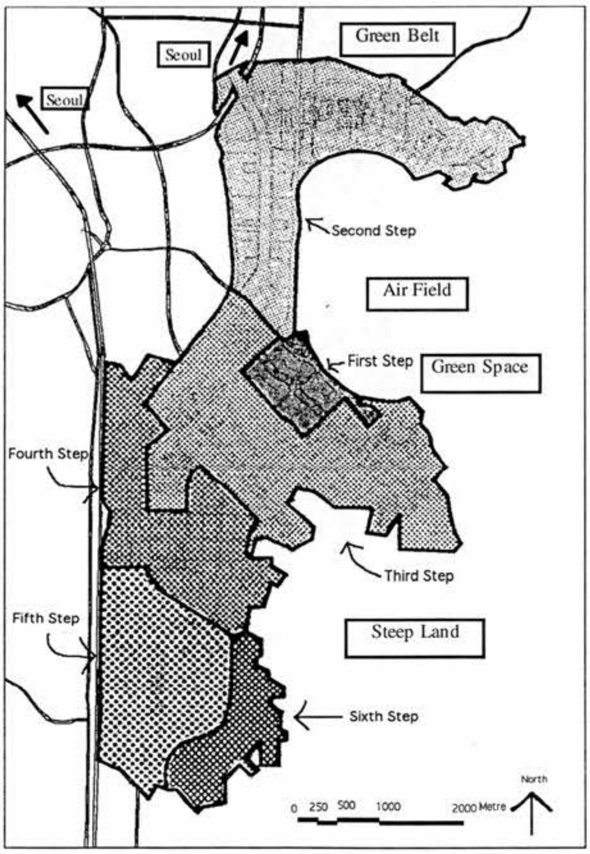


Figure 3-7. Development Steps of Pundang New Town

The planned area was divided into six zones, and each zone has residential areas, commercial areas, public and park areas, roads and other means of transport, plus an underground station. Around each underground station, office and commercial areas are located, making this city a self contained one. The two zones located in the centre part are the busiest commercial areas, surrounded by luxury apartments, while the southern zone is planned for elderly people with ample green parks areas nearby.[32] The northern zone, which is nearest to Seoul will be a centre for traffic entering and leaving the town, having a coach station with connections to other cities. A traditional market place, which requires good connections to the other areas, is located here as well. The six community zones are shown in Figure 3-8.

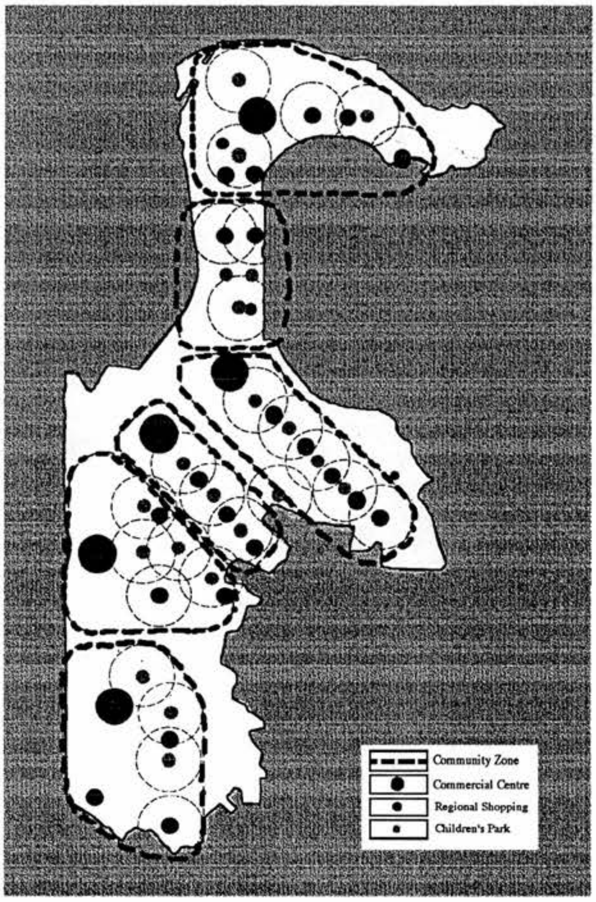


Figure 3-8. Community Zone in Pundang

Table 3-2. Land Use Plan - Pundang

Land use		Area (m^2)	Rate (%)
Housing	Apartment	4,366,142	23.79
	Attached house	1,159,413	6.31
	House	685,179	3.73
	Mixed (Apartment with Shop)	360,837	1.97
	Subtotal	**6,571,571**	**35.80**
Shopping-office Area	Office	688,190	3.75
	Regional shopping	542,824	2.96
	Central shopping	525,116	2.86
	Subtotal	**1,756,130**	**9.57**
Public Area	Park and open space	3,807,690	21.86
	Road	3,279,825	17.87
	River	1,224,768	6.95
	School	714,750	3.88
	Pedestrian road	233,365	1.22
	Public office	194,600	1.06
	Stadium	195,000	0.73
	Bus and train station	64,810	0.52
	Religion facility	56,080	0.31
	Library	25,500	0.14
	Hospital	34,150	0.19
	Others	209,337	1.08
	Subtotal	**10,025,755**	**54.63**
Total		**18,353,476**	**100.00**

Source: Ministry of Construction, Government of Korea

The housing area of the town is 35.8% of the total area. It is a relatively small portion of land compared to other new town plans, but since most of the housing consists of high-rise apartments, the population density in Pundang is higher than that of a western new town. Traffic problems are difficult to solve, but different from the British case. Whilst the problem in Milton Keynes in England, for example, lies in operating the public traffic system because of low-density development, the main issue in Pundang is to make a proper road system for heavy traffic within the city and for connecting other cities.[33] Parks and open spaces cover about 21 per cent of the city. A big central park is located in the middle of the planned area, six medium size parks are located separately, and lots of children's parks are located at the children's access distance of around 250 metres. The land use plan of Pundang is shown in table 3-2.

A high density urban area requires an efficient road system. Almost every land block is surrounded by 30 to 40 m-wide roads that connect the residential areas to the commercial and public areas. Several motorways provide a convenient approach to Seoul and other suburban new towns and existing cities. An underground system has been in operation since the middle of 1994, running from Pundang to Seoul. Pedestrian streets have been provided as safe walking paths leading to regional parks, children's parks and open spaces. About 30 per cent of the land is provided for green space to avoid a dull concrete building accumulation.

3-4-3. Apartment Construction in Pundang

The residential area in Pundang is divided into house areas, attached house areas, and apartment areas. Land area for apartment buildings is about 75 percent of the total residential area, while proposed housing unit number of apartments is about 90 percent of the total housing unit number (around 88 thousand). An apartment estate has some kind of barrier between other estates or buildings. The barrier can be a physical barrier using walls alongside the site, but normally wide roads surrounding the estate are used as a barrier. In addition to wide roads, most estates are on a different altitude from the road, this acting as a barrier. Trees are usually planted in these steep land areas between estates and roads.

Each estate has a certain number of apartment buildings (tower blocks). Usually one estate contains 10 to 20 apartment buildings consisting of 700 to 1,500 housing units. The size of estate, however, varies from 3 or 4 apartment buildings with around 200 housing units to over 40 apartment blocks with over 3,000 housing unit according to the size of the land block. The largest block in Pundang has 50 apartment buildings which has 2,598 housing units, or 41 buildings with 3,028 housing units. Some small estates, which have just two or three apartment buildings, combine together. A group of such small estates combined into one estate usually has more than 10 apartment buildings. Details are shown in Appendix 1, at the end of this thesis.

Some apartment estates in Seoul have over 300 per cent of plot ratio[34], which means total floor area of the building is more than three times bigger the land area. In office or commercial areas the plot ratio is often more than 1,000 per cent that of the city centre, but residential areas have to be different from that. To get a proper condition for homes, open spaces should be bigger than the floor area, which means an average plot ratio of about 50 percent. However, this is impossible if the total land area is too small to accommodate the populations. In the case of Pundang, the plot ratio is slightly lower than that of Seoul. Apartment estates have plot ratios varying from 110 per cent to 250 percent according to the location, but the majority of them are over 150 percent. To satisfy this plot ratio and to have more open spaces, apartment buildings tend to be higher. Plot ratio in each land block in Pundang is shown in Figure 3-9.

Each construction company was allocated to build apartment buildings and commercial facilities. The Korea National Housing Corporation, as a public company, builds mainly apartments for rent and small-sized apartments while private companies tend to build larger ones. The construction companies sell the apartments before they start to construct, and people need to pay for them in instalments before they can move into the apartments. Each construction company decides when they sell and construct the apartments, and advertises the merits of their apartments. In Pundang, the government helped the companies to decide the date of selling procedures. Four model apartment groups started to sell the apartments from the end of 1989 and people moved into these model apartments from September 1991 (for 16 storey-high or lower buildings), and from June 1992 (for buildings of at least 17 storeys). As the sequences, 16 steps of selling procedures were given to the buyers and the last apartments was occupied by the residents at the end of 1996.

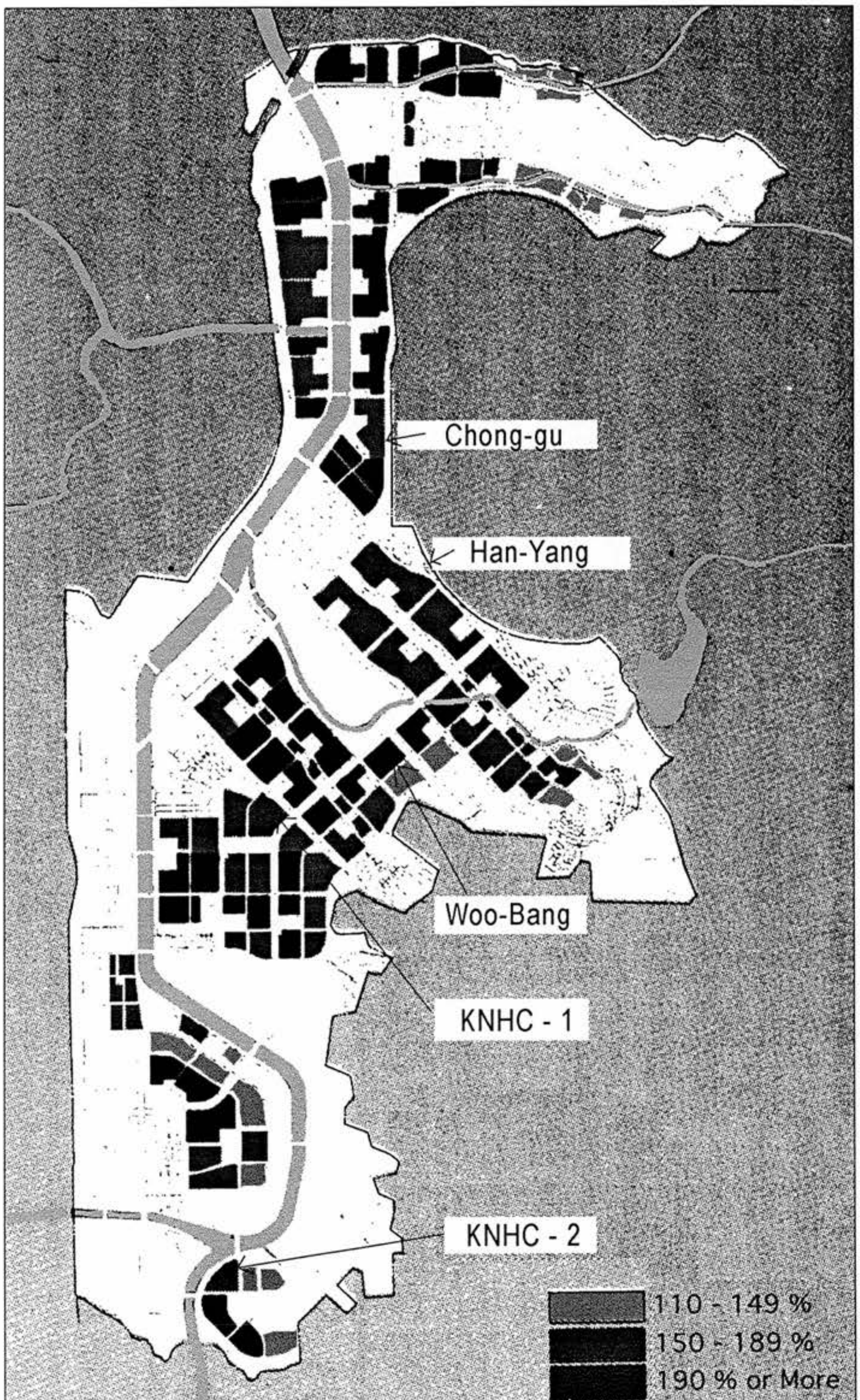


Figure 3-9. Plot Ratio of Apartment Estates in Pundang

The construction companies developed each land block mainly for the apartment buildings and some small grocery shops. Construction companies try to give an identity to their estates through the height of apartment buildings, colour, open spaces, sports facilities and so on. However, the high rise apartment blocks are recognised as a group rather than a composition of separate buildings or units. One of the reasons is the relatively short construction period of the development. In the case of Milton Keynes, in Britain, each block has quite a different form, from the mellowed and jumbled appearance of a medieval village in Eaglestone, to the six parallel rows of houses grouped into three pairs in Netherfield. In Pundang, the shape of each site may affect each master plan, but the image is nearly the same.

Five estates in Pundang are selected as examples of current high-rise apartments. Three of them are from private companies, and the remaining two are from Korea National Housing Cooperation (KNHC). The details of each estate are shown in Table 3-3, whilst the location of each estate is found in Figure 3-9.

Table 3-3. Details of Selected Apartment Estates in Pundang

	Chonggu (B26-1-2)	Hanyang (A1-3)	Woobang (C12-8)	KNHC-1 (D2-4)	KNHC-2 (F2-13)
Land size (square metres)	49,415	124,210	43,218	59,923	24,601
Number of housing units	710	2,419	811	1,088	563
Number of buildings	13	33	12	17	5
Plot ratio (%)	170	211	212	161	190
Footprint ratio (%)		16.19	18.05	13.13	11.39
Car parking space (car no.)		2,268	979		
Green space ratio (%)		30.95	31.2		40.94
Construction period		Nov 89 - Jun 92	Apr 91 - Jun 94		
Occupation date	Aug 92 & Mar 93	Sep 91 & Jun 92	Jun 94		

Source: Ministry of Construction, Government of Korea

Each estate has the role of a village with (a) public place(s), small shopping centres, sports facilities and some open spaces or gardens, giving people the opportunity to communicate with each other. The pressure of land price, however, prevents there being enough spaces for these facilities, and most of the open land is used as car parking space.

Unit plans are also similar to each other, whether they are big or small. Living rooms and master bedrooms face south or east, to gain maximum sunshine. This preference of orientation prevents there being a variety of designs. For the larger-sized apartments, two apartment units are located in each staircase with a lift, and for the smaller-sized apartments, a corridor is located in the opposite side of the preferable orientation, north or west, to connect between housing units and a staircase with lift(s). Details of estates, apartment buildings and unit plans are assessed in Chapter 5.

3-5. Problems of Current High-Rise Apartment Development

3-5-1. Quantity or Quality

The pressure of housing unit numbers has been stressed to the Government for a long time. Massive housing construction in Korea is an unavoidable phenomena, and the number of apartment buildings has grown fast since this is an easy way to accommodate people in a relatively short time. The total number of housing units increased by 30.2% between 1990 and 1995. The number of apartment units increased by 111.7% in the same period, with the number of units rising from 1,628 thousand in 1990 to 3,447 thousand in 1995.[35] Therefore, the percentage of houses in 1995 was less than half (47.6%) of the total housing units, compared with 66 percent in 1990.

Table 3-4 Number of Housing Units by Types in 1990 and 1995

Unit : 1,000 units (%)

Year	House	Apartment	Others	Total
1990	4,727 (66.0)	1,628 (22.7)	805 (11.2)	7,160 (100.0)
1995	4,383 (47.6)	3,447 (37.4)	1,385 (15.0)	9,216 (100.0)
Growth /Reduction (Rate)	Δ 344 (Δ 7.3)	1,819 (111.7)	580 (72.0)	2,055 (28.7)

Source: Daily Newspaper, **Chosun Ilbo**, 31 March 1996

Government plans for the amount of housing construction in 1996 is still substantial, about 500 - 600 thousand units, including 200 thousand small size apartments (18 PY or less).[36] Under these circumstances, fast construction, producing massive units, is more important for apartment construction rather than producing good quality apartments.

Apartment buildings built throughout the 1960s and 1970s, which are now around twenty or thirty years old, have been reconstructed since the late 1980s. Lack of technology and experience in those days resulted in many faults in the buildings, thus the building life is shorter than a normal concrete building, whose life is usually around sixty years. Furthermore, physical defects aside, social requirements may also make an apartment building life shorter, since the lifestyle and economic abilities of people have changed due to the enormous economic growth. Shortage of land area in the big cities is contributing to the trend of redeveloping the existing estates, thus further reducing the life-time of buildings. When a reconstruction takes place, the density of the area is usually doubled or tripled. Construction companies do not tend to worry about building life, because reconstruction could be easily done as required. Another point about construction companies is that sales of apartment units are at the end of the whole process of apartment construction. When they finish selling the units, they do not need to worry about the residents. Management and maintenance are the roles of other companies.

Government policy for price stabilisation is another reason for low quality apartments. The shortage of housing units and the massive increase in family units have led to a huge demand for housing units. Naturally, the price of houses and apartments may have increased enormously because of the above reasons and due to the rise in people's incomes as a result of fast economic growth. If the price of new apartments were left to market forces, many people could not afford to buy their homes. The Government has restricted the price of new apartments according to the size of the units. The price of a new apartment is usually set at between half and two-thirds of the price of existing apartments. In order to prevent the reselling of new apartments, when one household buys a new apartment unit, another new apartment unit cannot be bought within the following five years, unless unsold units remain after selling procedures.

Because of massive production of new apartment units in a relatively short period, many apartment units have remained unsold in the 1990s. Construction companies have been finding it difficult to survive, because of the restricted prices and unsold units. Many of them, especially small-sized companies, were bankrupted in this period. The positive thing here is that construction companies are forced to produce good quality apartments if they wish to survive. As a result, there is greater competition among them, with better efforts to produce good quality apartments. Each company tries to show its own merits through differentiation and higher standards. New technology and design methods are investigated by many construction companies for their own survival. People's recognition of the environment will push construction companies to design and build environmentally sound apartments. One company is trying to include roof areas and basement car parking areas in its designs, while others focus on the prevention of noise pollution or providing each unit with gardens. One company, named Kumho, even provides an opportunity for future residents to design their own home and after services.[37] Some companies collaborate on apartment construction to reduce risk, because of excess competition.[38]

3-5-2. Construction Accidents in the 1990s

Since there was a great change in the number of housing units in the late 1980s, the shortage of labour and building materials became a big social problem. Even if there were plenty of raw materials, the manufacture of building material could not fulfil demand. For the high-rise apartment buildings, ready mixed concrete was the biggest problem, since it could not be prepared before the construction. Massive construction sites all over the country require a large amount of ready mixed concrete, while concrete dump trucks are limited. Furthermore, unskilled labour has been employed because of a shortage of skilled labour. Consequently, the potential for an accident in many buildings built in this period is great.

Fortunately, there has been no such accident in apartment buildings, as experienced in earlier times.[39] However, there were two serious accidents in the construction industry in the middle 1990s. One of them was the collapse of the Seongsoo Bridge over the Han River, and the other was the collapse of the Sampoong Department Store. Both of which are in Seoul, calling into question the safety of all buildings. Like the collapse of the Wawoo apartment building in 1970, which was a turning point for the Korean construction industry, the two accidents in the mid-1990s, may signal a further turning point for the construction industry in Korea.

3-5-3. High-Rise Apartment Estates

Unlike British towns which have developed in line with the roads, Korean towns have developed through communities within certain barriers. Apartment developments may also depend on the cultural basis. While it is easy to find an apartment estate next to through-passing roads in Britain, there are certain barriers between apartment estates and through-passing roads in most Korean apartments. Therefore, when a certain number of apartment buildings is constructed, the design of the estate must be taken into account. The size of estates has grown, since it is easy to build many units in the same place. People also prefer to have bigger estates, because this can include more convenient facilities such as community areas, shops, leisure centres, kindergartens, and so on.

The high-rise is also an attractive form for the people in Korea, because higher density estate through high-rise can have more facilities and open spaces within the estate, without reducing open spaces and gardens. However, as the financial power of each family has grown, a lot of open spaces have turned into car parking places, even though there are other big parking spaces underground.

Summary of the Chapter

Within less than forty years, apartment buildings have changed the meaning of housing or homes in Korea. Although people feel uncomfortable with apartment buildings which started to appear in the late 1950s and the 1960s, they have adjusted themselves to the changed situations without definitive difficulties. One of the reasons is that people have gained an ability to adapt themselves to new circumstances through the process of fitting into other fast economic and social changes. During the 1970s and 1980s, apartments became luxurious and the buildings tended to become taller and taller, accompanied by high-density. Apartments, especially high-rise, are now an established form of Korean housing, even though there are still some problems to overcome.

The amount and rate of apartment construction since the late 1980s has increased enormously, since the problem of shortage of housing units in the early 1980s is one of the most notorious social problems in Korea, especially in big cities.

Continuous increase of housing construction for a further few decades will be an unavoidable phenomenon, if the government wants to control the target of housing spread rate in the near future. In the capital region alone, the target for housing construction between 1998 and 2002 for five years is enormous, reaching 1,350,000 units. To accomplish this target, some 270, 000 housing units will be constructed every year during this period.[40] Along with an increase in quantity, various types of apartments for a vast range of residents are required in future development. Social trends such as the increase of single families, more westernised life-styles and preference for greater space should be accounted for in future housing construction.

Among those issues, environmental concerns about construction and the life of a building need to be dealt with, as residents are eager to have a pollution-free environment. The regulations set down at international environmental conferences will affect the building industry as well, which requires energy-efficient construction and building operation. The success of future housing development will strongly depend on the concern of environmental impact assessment during the building's life-cycle. In the next chapter, the items of sustainable development in high-rise apartments are categorised, to develop a tool for assessing the sustainability of Korean high-rise apartment buildings, which will be shown in Chapter 5.

Notes and References

* marked after a number is written in Korean. The name of books in Korean will be shown at the end of the Bibliography.

1 Roderick J. Lawrence, *Housing, Dwellings and Homes - Design theory, research and practice*, p47.

2 * The Governmental Law, *Housing Construction Promotion Law*, Number 3.

3 Every apartment building over 6 storeys high requires a lift system by the Architecture Law (building regulation).

4 Housing spread rate is the rate of the number of housing units over the number of households. For example, if 10 families live in a certain area with 8 housing units, the housing spread rate is 80%. Usually, homeless people rent just one or two rooms sharing with a landlord or other tenant(s) in a house or apartment.

5* Kang-Su Kim et al, *A Study on Improvement of Design Standard for Building Energy Saving*, Minister of Construction 1993, p35.

The building required energy saving plan is as follows.

1. Apartment which has 50 or more units with central heating facility.
2. Shopping or research complex with the total floor area 3000 square metre or more.
3. Hotel, dormitory, youth hostel or hospital with the total floor area 2000 square metre or more.
4. Public hot bath or swimming pool with the total floor area 500 square metre or more.
5. Commercial building with the total floor area 3000 square metre or more, and having central heating and cooling facility.
6. Any other building with the total floor area 10000 square metre or more, and having central heating and cooling facility.

6* Kang-Su Kim et al, *A Study on Improvement of Design Standard for Building Energy Saving*, Minister of Construction, 1993, p34.

7* Taegul Lee, *Social History of Korean Apartments*, p347.

8 * Taegul Lee, *Social History of Korean Apartments*, pp 347-348.

9 * Land development research, *The Third Land Development Plan (1992-2001),* 1991 p 1.

The changing name has a special meaning because it means the recognition of importance in social and cultural development in addition to the economic growth. Preserving social and cultural identity, combating crimes and being in harmony with the environment are a few examples which appeared in the Fifth Plan.

10 From the partition of Korea to the early 1970s, the economic condition in North Korea was better than that in its counterpart, even though the situation changed in that the GDP per person in the South was around ten times more than that in the North in the early 1990s. As competitors, both Koreas want to outdo the other in many ways; socially, politically and military power; the construction industry is just one example of where competition lies.

11 civil servants.

12 The Hilton Apartment in Hannam-Dong. It was located at the foot of Nam-san Mountain, which is in the middle of Seoul city. This apartment estate for foreign people was demolished in late 1994.

13 People usually use PY as a measurement index of area for the buildings in Korea. 1 PY is approximately 3.3 square metres.

14 The size of housing is divided according to the size of floor area. Housing units of 25.7 PY (84.81 m^2) of less are called KUKMIN, which means a member of a nation, or citizen, housing. This is mainly for the poorer people.

15* Taegul Lee, *Social History of Korean Apartments*,

16 Yoido island is a small island of 2.8 square kilometres in the central part of Seoul city located between two stretches of the Han river.

17* Sejinsa, *Apartment encyclopedia*, Sejin Kihaek, 1994, p1.

18* KNHC, *Housing statistics Yearbook 1994*, KNHC, p99.

19* J. Seo, *Meaning and Prospective of New Town Development in the Capital Area*, p10.

20* KLDC, *Pundang*, 1992, p1.

21* KNHC, *Housing Statistics Yearbook 1994*, p

22 KNHC, *Housing Statistics Yearbook 1994*, pp 84-85

The trends of population and concentration in the Seoul metropolitan area are described in the Chapter 2.

23 One of 22 provinces in Seoul Metropolitan City.

24 * Youngwoo Keon, *Result and Question of Pundang New Town Development*, p19.

25* KNHC, *Housing Statistics Yearbook 1994*, pp 183 & 258-259.

Daily Newspaper, *Korea Herald*, 31 March 1996.

26 See page 102 for details.

27* Kunhyuck Ahn, *Characteristics of the New Town Development in the Capital Region*, p69.

28 See Figure 3-6 for the location.

29* Yongwoo Keon, *Result and Question of Pundang New Town Development*, p26.

30* KLDC, *Pundang*, 1992, p2.

31* Pyungki Kang, *Problems of New Town Developments*, 1989, p74.

32* City of Seongnam, *Pundang Urban Plan I*, 1992.

33 Samuel Kim, *New Towns and their Housing - comparing Korean and British Developments*, Edinburgh Architecture Research Volume 22, 1995 pp 42-58.

34 Plot ratio is the ratio of total floor area out of the total site area.

35 Daily Newspaper, *Chosun Ilbo*, 31 March 1996.

36 Daily Newspaper, *Chosun Ilbo*, 11 March 1996.

37 Daily Newspaper, *Seoul Sinmun*, 31 January 1996.

38 Daily Newspaper, *Chosun Ilbo*, 22 March 1996.

39 Collapse of the Wawoo apartment block in 1970. See page 93 for details.

40 Daily Newspaper, *Chung ang Ilbo*, 13 January 1997.

Chapter 4

A Tool for Environmental Impact Assessment for High-Rise Apartments (EIAHA)

Following previous chapters which dealt with a general understanding of the current global environmental situations, and indications of the Korean environment and housing, this chapter investigates sustainable building practices for high-rise apartment construction, leading to make the EIAHA (Environmental Impact Assessment for High-rise Apartment) as an environmental impact assessment tool.

The first section of this chapter introduces the EIAHA. After investigating the need for an environmental impact assessment of high-rise apartment developments in Korea, this section will identify a methodology for assessing environmental impact of high-rise apartment construction. The data taken here come mainly from the "BREDEM (Building Research Establishment Domestic Energy Model)", "SAP (The Government's Standard Assessment Procedure for energy rating of dwellings), a BRE Report, "Environmental Standard - Homes for a Greener World", and a BSRIA Report, "Environmental Code of Practice for Buildings and their Services". These data will form the basis of a method for assessing the environmental impact of high-rise apartment buildings.

The following sections explain each step of the EIAHA organised in the first section. Each section has two steps of the EIAHA, and the first two steps concern passive design strategies, which help to reduce energy consumption without decreasing thermal comfort. The second two steps are about the issue of building materials, complising general environmental issues and energy use for producing these materials. The third two steps deal with the consumption of energy during the building's occupation, which depends upon the efficiency of mechanical heating systems. Finally, the importance of a building's life-span for sustainable development will be discussed in the last two steps, dealing with life-cycle analysis of buildings in terms of management and maintenance. General elements of these items which apply to ordinary buildings are categorised first, followed by elements of high-rise apartment buildings.

The last section of this chapter will summarise the EIAHA. This will be itemised by using a credit system, which will provide an essential source for assessing Korean high-rise apartment developments which appear in the next chapter. These items will also be used for the assessment of high-rise apartment developments in other countries in Chapter 6, and the assessments in both chapters form the foundation for suggestions for future Korean high-rise apartment development in Chapter 7.

4-1. Introduction of the EIAHA

4-1-1. The Need for an Environmental Impact Assessment of Korean High-Rise Apartments

Environmental issues are not separable from social ones, and an approach to urban sustainability in eastern countries lies in reinterpreting and reinventing the dense city model, rejected by most western countries.[1] The trend of urban concentration, which has resulted in the need for high-density urban development in Korea as well as in many other eastern countries, requires different approaches for the development of its cities from western countries. The preference of high-rise dwellings with ample open spaces rather than a low-rise high-density development leads to different strategies in housing construction. It seems to be difficult to think of alternatives to high-rise apartment construction because of the massive requirement of housing units and lack of land in Korea. The target set for the sustainable future should embrace this trend, rather than searching for alternative types of housing construction.

Recently, around 650,000 housing units are being built each year in Korea, with 250,000 in the capital region alone, most of them high-rise apartments. This number will further increase over the next few years until early next century.[2] A little improvement in each unit as regards the environment will make an enormous contribution to the sustainable global environment when it is accumulated. There are presently no such strategies to have pollution-free construction, but careful attention and implementation has the potential to improve the global environmental situation as well as the local and regional environment. The aim of looking at the environmental impact assessment of high-rise apartments in Korea is to increase awareness of global environmental issues and the role high-rise apartment development plays in such issues.

The environmental conditions in Korea, especially in big cities, has improved for a few decades, since the importance of the environment has been recognised. Air, water and other features of the natural environment, originally "gifts from nature", were destroyed during massive economic growth in the 1950s and 1960s, but started to be improved from the 1980s, as shown in Chapter 2. Improvement of the regional environment, however, is not enough to sustain the world, because the gravity of global environmental disorders has never been more important than now. Cooperation with international efforts are now required and Korea has also joined many international environmental treaties recently (see Chapter 2). It is high time to think about the implementation of these treaties by achieving the targets from industries as well as establishing targets for international treaties such as CO_2 reduction or CFCs extinction. Although it has not yet been established by how much CO_2 emissions should be reduced by a certain time, there have been efforts to build up some regulations and this will soon be reflected in national governmental policy.

Since buildings and construction industries have a great impact on the environment, high-rise apartments, which constitute the biggest proportion of the building industry in Korea, have a great potential to reduce environmental impact during their life-span, including in their production, use and maintenance, and demolition, if careful consideration is taken. Through energy saving design and extending the life of high-rise apartment buildings, a small contribution to the sustainable global environment from the Korean construction industry will be obtained. Assessment of current development trends is vital to improve the situation, and will lead to the establishment of its own tool for high-rise apartments. Starting from the gathering of information from references, an environmental impact assessment method for high-rise apartment is developed.

4-1-2. Analysis of Current Environment/Energy Assessment Tools

Although there is the need to have a proper environment/energy assessment tool for high-rise apartment buildings, it is difficult to find one in Korea. Current energy policies focus on the reduction of energy use without a proper holistic assessment, but deal with a few items separately. The references of current assessment tools described here, therefore, are mainly from the cases of the United Kingdom.

The data taken here are mostly from the "Environmental Standard - Homes for a Greener World" in the BRE Report 1995, a first and recent revision of BREEAM/New Homes 1991, which is one of the Building Research Establishment Environmental Assessment Method (BREEAM) series. Before looking at the 'Environmental Standard', BREDEM (Building Research Establishment Domestic Energy Model) and SAP (The Government's Standard Assessment Procedure for energy rating of dwellings) analyses are investigated. Further references are taken from a BSRIA Reort, 'Environmental Code of Practice for Buildings and their services' and some 'Life Cycle Analysis' from various literatures.

BREDEM

BREDEM (Building Research Establishment Domestic Energy Model) is a model for the calculation of the annual energy requirements of domestic buildings, and for the estimation of savings resulting from energy conservation measures. In BREDEM, it is assumed that estimates of the energy requirements of and the environmental conditions in houses are required for a variety of purposes such as; the assessment of alternative options during the design of new houses; prediction of the effect of conservation measures which might be applied to existing properties; estimation of energy efficiency at time of purchase; calculation of the internal environment for given energy inputs; prediction of national energy resource requirements.[3]

BREDEM provides the means to calculate the energy savings and internal temperature changes resulting from a conservation measure or a combination of measures. Energy assessments are divided into energy use for space heating and energy use for others.

In order to get proper assessment for energy use for space heating, the factors are broadly classified under five headings;[4]

1. Physical characteristics of the house: U-value, infiltration rates, thermal capacity, internal heat transfers.
2. Physical characteristics of the heating system - efficiency, ability to respond to changes in heat requirement, controls
3. User requirements - the temperature level required by the user and variations in this level both in different parts of the house and at different times of the day; window opening.
4. Internal heat gains arising from the activities of the occupants.
5. External weather conditions, including temperature, sun, wind.

Data are included on energy used for other purposes, namely; hot water, cooking, lighting and electrical appliances. BREDEM has developed later versions with names such as BREDEM-2 and BREDEM-3. BREDEM series are references for further assessment tools such as SAP (The Government's Standard Assessment Procedure for energy rating of dwellings) and Environmental Standard - Homes for a Greener World.

SAP

SAP is for producing an energy rating for a dwelling, based on calculated annual energy cost for space and water heating. The rating is normalised for floor area and is expressed on a scale of 1-100: the higher the number, the better the standard. The method of calculating the rating is set out in the form of a worksheet. A calculation is carried out by completing the numbered entries in the worksheet, and the worksheet has a sequence of calculation comprising; [5]

1. Dwelling dimensions,
2. Ventilation rate,
3. Heat losses,
4. Water heating energy requirements,
5. Internal gains,
6. Solar gains and utilisation factor,
7. Mean internal temperature,
8. Degree-days,
9. Space heating requirements,
10. Fuel costs,
11. Energy cost rating (represented by SAP).

SAP rating scale was chosen to cover a wide spectrum of energy costs, rising by one unit as cost falls by a constant percentage. A SAP rating of 60 or below indicates the need for a higher standard of fabric insulation. A SAP calculation is a requirement under Building Regulations Part L (conservation of fuel and power) for new dwellings in England and Wales.

Current assessment shows that housing of the local authority sector has a mean SAP rating of 34.4 and 17 % of dwellings with ratings below 20. It is generally less energy efficient than the owner-occupied sector (mean SAP 32.7 and under 10% of dwellings below 20) but more efficient than the private rented stock (mean SAP 21.7 and 47% of dwellings below 20).[6] According to a current practice case study, improvement of thermal insulation through energy efficient refurbishment of high-rise housing is enormous, and some SAP rating increased about 40 points. (e.g., Artley Court/Compton Court 1-bed mid flat from 24 to 65, and Chamberlain Gardens 1-bed mid flat from 17 to 59)[7]

Environmental Standard - Home for a Greener World

The Environmental Standard contains global and local environmental issues and is also concerned with the indoor environment. The overall focus on the impact on the global environment is to maximise energy efficiency and to conserve fuel because: burning any fossil fuel leads to the production of carbon dioxide and the potential for global warming through the greenhouse effect; burning fossil fuels depletes a valuable natural resource; and oxides of nitrogen and sulphur are emitted when fossil fuels are burnt, thus contributing to acid rain and damage to the natural environment.[8]

In the report, a credit system was established to reduce the environmental impact of housing. There are a certain amount of credits for the "Environmental Standard Award", and further more credits are required for the "Homes for a Greener World Competition". The amount of energy requirement as well as the fuel type determines the amount of CO_2 emission throughout the year. Energy requirements are very complicated because they depend on the regional climatic condition, use of renewable energy resources mainly from the sun, and an efficient heating system.

The available credits for the Environmental Standard award is 22 points; of which 13 points are for global issues, 5 points for local and 4 points for indoor issues. Among them, 12 points are the minimum requirement; 8 for global issues (5 mandatory and 3 additional otpional), 2 for local (0 mandatory and 2 additional optional) and 2 for indoor issues (1 mandatory and 1 additional optional). The global issues include CO_2 emission rate, ozone depletion potential, timber, and recycling of materials. For 'Homes for a Greener World competition', the required minimum credits increase to 18 points; 11 for global issues (8 mandatory and 3 additional optional), 4 for local (1 mandatory and 3 additional optional) and 3 for indoor issues (2 mandatory and 1 addional optional), while the available credits remain 22 points. A summary of the Environmental Standard Award and the Homes for a Greener World Competition for global issues and use of resources is shown in Table 4-1.

Review of the above Three Assessment Tools

BREDEM is a pioneer tool for housing energy assessment. The tool analyses the elements which affect energy consumption. Adopted from the concept of BREDEM, SAP created numerical values for assessing energy consumption for housing. SAP only deals with energy use for heating and hot water, and the values come from the price of energy used rather than the amount of energy (e.g. KWH or GJ). This assessment, therefore, is strongly based on economical factors rather than environmental ones. BRE has developed the idea of environmental assessment through a series of BREEAMs (BRE Environmental Assessment Method). The Environmental Standard is the latest of them and deals with the environmental assessment of dwellings. This assessment includes not only carbon dioxide emission due to energy consumption, but also other global issues such as ozone depleting gases, timber, and renewable and recycled resources as well as local and indoor issues. The assessment for CO_2 emissions in this assessment tool uses emission factors described in SAP.

The first two assessment tools, BREDEM and SAP focus on the energy consumption during the building operation, mainly for space and water heating. In this context, heating source and heat loss of the building envelope were investigated. A big difference between the two tools is that while BREDEM only assesses current energy

Table 4-1. Global Issues and Use of Resources in the Environmental Standard Award and the Homes for a Greener World Competition

Environmental Standard Award
Mandatory
* CO_2 emission rate equal to or less than a maximum allowable value which depends on the floor area of the dwelling (one credit)
* All insulants with ozone depletion potential of 0.10 or less
* All solid timber from all managed, regulated sources, or suitable re-used timber
* All timber panel products from well managed sources or suitable re-used timber
* Storage containers for recyclable household waste
Optional
* CO_2 emission rate equal to or less than a maximum allowable value which depends on the floor area of the dwelling (one more credit for less emission rate)
* All insulants with ozone depletion potential of zero
* Low-energy lighting
* Provision of gas cooking point
* At least 50% recycled/re-used material in roof covering
* At least 50% recycled/re-used material in walls or floor
* Demolition materials for fill and hard core
* Timber frame construction

The Homes for a Greener World Competition
Mandatory
* 2 credits for CO_2 emissions such that CO_2 emission rate is equal to or less than a maximum allowable value which depends on the floor area of the dwelling
* All insulants with ozone depletion potential of zero (2 credits)
* All solid timber from all managed regulated sources or suitable re-used timber
* All timber-panel products from well managed, regulated sources or suitable re-used timber
* Storage containers for recyclable household waste
* Low energy lighting
Optional
* Provision of gas cooking point
* At least 50% recycled/re-used material in roof covering
* At least 50% recycled/re-used material in walls or floor
* Demolition materials for fill and hardcore
* Timber frame construction

Source : Josephine J. Prior and Paul B. Bartlett, *Environmental Standard - Homes for a Greener World*, BRE Report, 1995, p5 & 25.

use, SAP produces a rating system whereby people can get a certain value for their house in terms of energy use. They are not sufficient for assessing the full environmental impact of housing, since there are many other factors apart from energy use.

Environment Standard, the recent revision of BREEAM, is an upgraded environmental assessment tool, which includes a variety of categories from global issues to local and indoor issues. It describes how certain items are required for a greener environment, and further options are outlined for a competition. Details of the calculation of energy use and carbon dioxide emission are adapted from SAP. Although it deals with a variety of items for a better environment, the assessment misses some very important elements; life-cycle assessment and embodied energy of building materials.

Further Examples of Environmental Assessment

For the sustainable future, the assessment of high-rise apartment buildings is better made through a life-span analysis. Although a building may require less energy during its operation, it is not good enough if it requires a massive amount of energy in construction and repair procedures. If the life of a building is extremely short, it cannot be environmentally friendly, regardless of energy and resource consumption during construction and maintenance. If one building can last twice as long as another building, for example, the environmental impact during construction of the former may be half that of the latter. According to recent research, embodied energy for a building's subsequent maintenance and refurbishment for over sixty years is less than initial embodied energy, ranging from half to two thirds, in office buildings.[9] Initial embodied energy for the construction of office buildings is usually equivalent to energy-in-use for five to ten years. For residential buildings, embodied energy for construction versus energy in use are very different according to the type. Whilst embodied energy for construction is just three times as much as that for a one year operation for bungalows, embodied energy for construction is equivalent to the energy for 7.7 years' operation for high-rise apartment buildings. [10]

Environmental Code of Practice for Buildings and their Services

The environmental code of practice published by BSRIA (Building Services Research and Information Association) describes the environmental impact of a building through the life-cycle of a building from 'Pre-design' through 'Design', 'Preparing to Build', 'Construction', 'Occupation', and 'Refurbishment', to 'Demolition' stages. Each stage contains a number of recommendations and notes. Further information is described in each stage, including with some 'Rules of Thumb', 'Pitfalls' and 'New Ground'.

BSRIA mentioned in its guidelines that buildings are not exempt from the growing market for green products and the development of environmental labelling. To satisfy a number of criteria, buildings will be required to follow the guidelines below; [11]

They should not:

* Endanger the health of the occupants or any other parties;
* Cause unnecessary damage to the natural environment or consume a disproportionate amount of energy during construction, use or disposal;
* Cause unnecessary waste due to short life, poor design, or less than ideal construction and manufacturing procedures;
* Use materials from threatened species or environments.

and they should:

* Enhance living, working and leisure environments;
* Consume minimum energy over their life cycle;
* Generate minimum waste over their life cycle;
* Use renewable resources wherever possible.

In this code of practice, energy requirement for manufacturing and/or producing selected building materials was indicated, as well as ecological assessment of building materials. A massive amount of energy is used in the manufacturing and transportation of materials and constructing with them. It is now necessary to know what impact building materials have, and which material has more or less impact on energy consumption as well as other environmental elements.

Life Cycle Analysis

Life cycle analysis (LCA) is a technique which was developed in the early 1970s, when the energy crisis gave rise to the need for energy conservation. Recent research shows that there is large scale discrepancy in pollutant emissions for the same size apartments over a given sixty year lifetime.[12] The results show that one type is 2.7 times less damaging in its effect upon the environment than the other.

A life cycle assessment produces a quantified inventory of the resources used and the emissions associated with the production of a particular item or service. The guiding principle of the EC ecolabelling scheme is that, by considering the impacts on the environment through the whole life cycle of a particular product group, the individual products that have the smallest effect on the environment can be identified.

'ECO-LABEL for Building Products' developed by 'Swiss Community of Interests for Building Biology/Building Ecology (SIB)' also argued about the importance of the life-cycle stage of environmental assessment. Assessment starts from the 'Manufacture' stage which includes 'Raw Material Mining/Harvesting Primary Energy' and 'Production/Processing Distribution'. The second stage is 'Utilisation' which encompasses 'Construction /Installation' and 'Use/Cleaning'. The third stage is 'Maintenance', including 'Renovation/Rehabilitation' and 'Demolition/Re-structuring'. The final stage is 'Disposal' which include 'Re-use or Recycling' and 'Deposition/ Incineration'. Each step was evaluated and colour coded green, yellow or red representing low environmental impact, medium environmental impact and high environmental impact respectively.[13]

The 'Eco-Label for Building Products' shows that Deposition and Incineration, which is the last stage of life-cycle assessment, has a high environmental impact. This stage affects the landscape picture, flora and fauna, and refuse / waste problems. The steps which have Medium Environmental Impact are; 'Raw Material Mining/ Harvesting Primary Energy' which affects power consumption and air impact; 'Use/Cleaning' which relates to the health of the people and social aspects; 'Demolition/Re-structuring' which causes refuse/waste and transportation problem; and 'Re-use or Recycling' which affects social aspects and water impact. The others - 'Production/Processing Distribution', Construction/Installation' and 'Renovation and Rehabilitation' - have a low environmental impact.

4-1-3. Development of the EIAHA

The EIAHA is developed by using the above references. In the EIAHA, the environmental impacts of high-rise apartments are categorised item by item. When the EIAHA is applied to a building, other environmental impact items such as ozone depletion, tropical hardwood and pollution problems are dealt with, while energy consumption issues are the main stream of the assessment. Energy used for apartment buildings is divided into; energy for construction, which includes the embodied energy of building materials; energy for repair and maintenance; and energy for building operations, such as heating, cooling, lighting and other electricity.

Some current assessment tools, such as the BREDEM and the SAP, deal with producing a certain value according to energy consumption during the building operation, as seen before. The EIAHA, however, investigates energy consumption further, in order to get a proper assessment, by adopting the methods of life-cycle environmental impact assessment.

The EIAHA starts with the design stage, where careful passive design can save energy while keeping thermally comfortable conditions. Passive design includes building orientation and unit plan, where effective amount of solar energy can be acquired without adding more materials. The use of sun-space for collecting winter sun heat is also an important element to reduce heating load. Passive design includes thermal insulation, where additional insulation materials are required. These materials usually embody a lot of energy, but research shows that this energy consumption can be taken off because of the savings during the building operation.

The EIAHA goes on to the construction process, where issues of materials are mainly discussed. As shown in 'ECO-Label for Building Products' in the previous section, the construction and installation stages of building have less environmental impact compared to the energy use for raw material mining. The transportation of building materials also requires massive energy consumption, especially for heavy materials. The assessment starts with general items for building materials such as ecology and health issues, and then energy content for producing building materials, so called embodied energy, will be examined, in order to find out how much energy is required to make a building.

Energy is also used during the building operation. Energy use in the operation of apartment buildings is categorised into energy for heating, hot water and electricity. Energy for electricity involves lighting, home entertainment, lift operation, etc., as well as using mechanical cooling facilities in summer. While energy use for electricity mostly depends on the life-style of the residents, there is a wide difference in the amount of energy use for heating according to the heating mode and the operation of a heating system. This part, therefore, mainly deals with the efficiency of a heating system, comprising heating modes and their operation.

Finally, the importance of a building's life in terms of environmental costs will be discussed. Although there are certain economical or social benefits from redeveloping existing apartment estates, there is also an enormous negative effect on the environment, through the use of materials and energy, and the production of waste.

Apart from materials used and waste, which are also very important for sustainable development, energy consumption for demolishing old and reconstructing new apartment buildings is so great as to consider an alternative. The EIAHA deals with the assumption of building life with a reference of current trends. Since the life of building does not totally depend on the physical life - the life expectancy because of building deterioration -, further factors such as social and economical elements which affect building life will be investigated along with the establishment of management systems, maintenance and repair plans.

Elements of EIAHA are shown in Table 4-2. There are two steps in each category, complising eight steps. Each step has 10 credit points. Each step will be described throughout this chapter, and the details of credit points in EIAHA are shown at the end of this chapter (see table 4.10). Apartment buildings will be assessed good, medium or bad in each steps according to the credit points acquired: good for 8 points or more, medium for between 5 and 7, and bad for 4 points or less. The main purpose of this assessment is to look at the balance of each category, rather than to calculate how many points can be acquired. The suggestions will focus on making balance on each step, instead of maximising the total points.

Although the total credits mainly means higher performance of environmentally friendly development, the points cannot indicate the absolute value for the assessment. The points taken here are, therefore, relative, which means twice of the points does not equal to the half of the environmental impact. The numbers are just a sequence of the orders of preferences. It also does not have the same gravity on each step. The intention of categorising each step is to look at the balance of each item. The amount of total points does not always mean the order of environmental impact. The important thing here is to focus on the balance of each step.

Even the credit system is not perfect because of difficulties for deciding each point, using credit points is one of the clearest ways to look at the assessment. Targets in each step can be suggested for improving the credit points.

Table 4-2. Elements of EIAHA (Environmental Impact Assessment of High-rise Apartment)

Category	Step	Element
Passive Design	1. Passive Solar Design	1. Orientation (4 points) 2. Room arrangement (1 point) 3. Sun-space & Balcony (5 points)
	2. Insulation and Ventilation	1. U-value (4 points) 2. Window glazing (2 points) 3. Thermal break & Condensation (2 points) 4. Ventilation (2 points)
Building Material	3. Ecology and Health	1. CFC-free materials (3 points) 2. Tropical hardwood (3 points) 3. Health (2 points) 4. Recycled Materials (2 points)
	4. Materials' Embodied Energy	1. Establishment of the figure (4 points) 2. Value of embodied energy (6 points)
Heating System	5. Heating Mode	1. Heating Mode (5 points) 2. Fuel Type (5 points)
	6. Operation of Heating System	1. Control (2 points) 2. Metering (2 points) 3. Complaints (2 points) 4. Equality (2 points) 5. Comfortability (2 points)
Management and Maintenance	7. Building Life	1. Life-expectation (4 points) 2. Consideration of Easy Repair (3 points) 3. Social Aspect of Building Life (3 points)
	8. Management System	1. Establishment of management system (2 points) 2. Fund for maintenance (4 points) 3. Repair plan (4 points)

4-2. Passive Design Element

4-2-1. Climate and Comfort

Although human populations can survive in harsh climatic conditions, in areas ranging from tropical to arctic regions, the human body is comfortable in only a relatively narrow range of thermal conditions. Thermal comfort of human beings is governed by many physiological mechanisms of the human body and these vary from person to person. The principal factors affecting thermal comfort can be considered in various ways. Air temperature and humidity are critical factors for this comfort range, but there are others such as the movement of air, air quality, surface temperature and radiant condition.[14] Besides these physical conditions, there are personal variables such as activity, clothing, age and sex.[15] Therefore, it is difficult to get more than half of the people affected in any particular thermal environment to agree that the conditions are comfortable.[16]

In spite of a lot of variation depending on local climate and personal adaptation to it, which makes it difficult to create a certain agreement, there have been efforts to define a range of temperature and humidity levels known as 'the comfort zone', that most people regard as pleasant. The comfort zone is usually a temperature between about 18°C and 24°C with the relative humidity between about 30 and 65 percent,[17] even though these ranges can differ according to various physical and personal conditions.

At the same temperature, people can feel warmer as humidity increases. As temperatures increase, the effect of humidity on comfort becomes significant, while humidity has a comparatively small effect on comfort at lower temperatures. This reflects the physiological response of the body to depend increasingly on evaporation to lose heat as ambient air temperatures increase. More accurate methods for measuring the comfort range have been attempted through combining temperature and humidity, and one of the most widely used measures of the thermal environment is effective temperature (ET). It takes into account the combined effects of air temperature and humidity on comfort, because humidity levels can affect the perception of temperature. 85 °F (26.7 °C) in the relative humidity of 85 %, for example, has a relative feeling of 90 °F (32.2 °C) in the relative humidity of 50 %; or 90 °F (32.2°C) in 90 % is relevant to 100 °F (37.8 °C) in 50 %. [18]

Buildings were originally for protecting people from an uncomfortable environment. Conditions rarely combine in nature to give satisfactory thermal conditions, and buildings have an important function in providing thermal comfort. The interaction of building and thermal conditions is complex.[19] There are relevant points before designing buildings which lead to a comfortable thermal condition. To make buildings comfortable, for example, they should be kept within a suitable temperature range, which is not as wide as that in an uncontrolled external environment. Modern buildings have achieved a suitable indoor temperature through maintaining fairly constant internal conditions to provide comfort standards with the use of significant amounts of energy providing heating or cooling against a changing external environment. The amount of energy used could be reduced significantly if buildings adopted the principles of animal physiological control. To do this one first needs an understanding of human comfort and how energy is expended to provide it.[20]

For residential buildings, heating has always been considered a basic requirement in living-rooms and bedrooms for thermal comfort, when it is cold outside. When in use the living-room temperature should not fall below 16 °C, particularly in homes for the elderly. The normal requirement is for a minimum of 21 °C, so that heat sources should be capable of maintaining this temperature.[21] It is always recommendable to use renewable sources from solar energy for keeping a comfortable indoor temperature. If mechanical systems are required, heating systems should be selected not only for energy efficiency, but also for ease of operation. In the same way, cooling may be required on a hot summer day, especially with high humidity. Proper ventilation control and shading will prevent or reduce the use of mechanical cooling systems, which require a lot of energy to operate.

For apartment buildings, the requirement of energy for heating in an unit is usually less than that of a house in the same size. While heat loss occurs through six surfaces of the building fabric in a house, only two or three (maximum four) surfaces are adjacent to the outdoor uncontrolled environment in an apartment unit. Providing heat to many units using one heat generator is also a merit for energy efficiency. In this case, careful use of mechanical systems for generating and providing heat to each unit should be considered.

4-2-2. Passive Solar Design

Passive solar design is the first step of EIAHA. Passive solar design is simple and clear. Passive solar buildings are designed to collect energy from the sun to provide heating and lighting within the buildings, and to reject solar energy when it can lead to overheating. All buildings have an effect of passive solar design since they collect some solar energy, unless they are completely shaded. The task of the solar designer is to increase the useful heating and lighting whilst minimising the risks of overheating. Successful passive solar architecture has not only to combine solar heating, daylighting and passive cooling, but has also to create good external layouts and appearance, together with pleasant internal arrangements.[22]

Although the theory is simple, implementation of it is complicated. The heat gained in a building by radiation from the sun depends upon the area in which it is situated, because of the differences in geographical latitude of the site, which determine the height of the sun in the sky. The season of the year also affects the height of the sun in the sky. Even in the same latitude, the amount of solar energy can be different because the local cloud conditions block solar radiation. Orientation of the building on the site, such as whether rooms are facing south or north, is a vital element which an architect can use to improve the thermal condition of the building. Another point for efficient solar design is the angles between the sun and the building surfaces, because maximum gain occurs when surfaces are at right angles to the rays from the sun.[23]

Building materials also have an effect on passive solar design. Window glass is the most important because it can absorb or reflect radiation. The nature of the roof and walls is another, because heavy-weight materials behave differently to light-weight materials.

Preventing excessive heat gain and glare caused by direct sunshine is also a part of 'sun control' in a building. The devices for this are divided into two categories: external control and internal control. External controls are the most effective form of sun control because they minimise the radiant heat reaching the fabric of the building. Examples include external shutters, awnings, projecting eaves or floor slabs. Internal controls such as blinds give protection against glare and direct radiation. The system is less effective than controls outside the glass because the blind will absorb some solar heat and re-emit this heat into the room. Examples include curtains, blinds and internal shutters. Without additional devices, special glass is available which has the effect of preventing the transmission of most heat radiation, with only some loss of light transmission.[24]

Orientation is the most simple way to improve the thermal environment without adding energy both for operation and construction. South-facing, which is most efficient way to accept winter sun, gets 4 points in EIAHA, while north-facing gets no point. The orientation needs to accompany room arrangement, in here one point is given in the assessment. Using balcony is good way to improve thermal performance through getting heat in winter and avoiding it in summer. If accompanied with sunspace through installing windows outside the balcony space, indoor temperature in winter will rise more properly and this will get 5 points in EIAHA. Details are in table 4-10, at the end of the chapter.

4-2-3. Thermal Insulation and Ventilation

In order to maintain a constant temperature within a building, it is necessary to restrict the rate at which heat energy is exchanged with the surroundings. Thermal insulation is a major factor in reducing the loss of heat from buildings, or in reducing the flow of heat when temperature outside is greater than temperature inside. Adequate insulation should be a feature of good initial design, but insulation can also be added to existing buildings. Good thermal insulation will give savings in the amount of fuel needed and also in the energy needed to run the cooling plant. Good insulation can also reduce the time taken for a room to heat up to a comfortable temperature.[25]

However, careful instaliation of insulants to buildings is required, as poor installation can cause problems such as thermal bridges and condensation. Where gaps occur in the insulation, a cold bridge is created leading to a risk of condensation and additional energy loss. Strategies for avoiding a cold bridge at the roof/wall junction, for example, are; 'to carry the loft insulation over the wall plate and butt against the wall insulation; to cover the gap between ceiling joist and gable wall with insulation; and to extend the cold bridge path at the gable by overlapping the roof and wall insulation and using a low density block for the inner leaf.'[26]

As a standard of measuring the degree of insulation in materials, the thermal transmittance, or U-value(Unit: W/m^2K or $W/m^{2}{}^{\circ}C$), is used to measure the overall rate of heat transfer. Lower U-values mean better thermal insulation. Standard U-values will not always agree exactly with U-values measured on site, but they are needed as a common basis for comparing the thermal insulation of different types of structure and for predicting the heat losses from buildings.[27] In Korea, the unit used for thermal transmittance is the K-value ($kcal/m^2h^{\circ}C$) rather than U-value (W/m^2K). Since 1 W is about 0.86 kcal/h, 1 U-value is approximately 0.86 K-value.

Proper ventilation will prevent the use of air-conditioning, if the weather is not extremely hot. Ventilation is also important to improve indoor air quality.

In EIAHA, thermal insulation will have 8 points, comprising 4 points for U-value for wall insulation, 2 points for window glasing and 2 points for concerning thermal break and condensation. Ventilation has 2 points for concerning cross ventilation. The importance of cross ventilation will be increased, but most energy for temperate weather region is used for heating, on which thermal insulation has a great effect. Thermal insulation is also important for summer cooling.

4-3. The Issue of Building Materials

4-3-1. Environmental Impact of Materials

Building materials affect the environment in different ways. Some affect the environment within the buildings, including the use of asbestos products and solvent-based paints. For a sound environment within a building, materials should be clean and contain no pollutants or toxins, emit no biologically harmful vapours, dust, particles, or odours. They should also be resistant to bacteria, viruses, moulds, and other harmful micro-organisms, which will make the residents uncomfortable or even ill. All materials should also be radioactively safe and should not emit any harmful levels of radiation.[28]

In terms of a wider context, most materials have an impact on the global environment, through producing carbon dioxide and CFCs and consuming tropical hardwood from non-sustainable sources. Most building materials deplete resources, which leaves building materials scarce. All materials are responsible for some carbon dioxide emissions, during their processing or manufacture, and transport using energy. There have been many efforts to evaluate materials in terms of tons of carbon dioxide produced per ton of material and then to calculate the total amount of carbon dioxide produced per building component or appliance.[29] Details are explained in the discussion of embodied energy later in this section.

There are several ways that the substances which deplete ozone layer are commonly used in domestic buildings. Some insulation materials such as polyurethane foam produce CFCs as the expanding gas in insulants. This could be replaced in many cases by carbon dioxide, helium or argon. CFCs are also used in refrigerators, where the refrigerants can now be replaced by a mixture of propane and butane. As propellants in aerosol sprays such as paint or foam are a responsibility for production of CFCs as well. Carbon dioxide, helium, argon and even propane in certain circumstances can be used instead. In fire protection equipment , Halon, which is also a substance procuring ozone layer depletion, is produced. This gas can mainly be replaced by carbon dioxide.[30]

Until the development of technology for modern materials and extended transport systems, house-building materials were usually found locally. Traditional materials such as clay, lime, chalk and stone are still abundant, and timber can be replenished by properly managed forests. In addition, these materials are easily reused or recycled, they produce little or no pollution and they are reabsorbed into the natural cycles of the environment once their use as building materials is over. Most building materials were supplied from a local base, because transport was difficult and expensive, often costing more than the materials themselves. However, with improved transport systems, local materials could be dispersed to distant places and be used in inappropriate ways. The process of our gradual and inevitable transfer from local materials had started.[31] High-technology can, on the other hand, contribute optimisation of energy use. The list of technologies investigated in the EU-funded research project, for example, included; co-generation of heat and electricity with the heat powering a heat-pump for cooling; the co-generation fuelled by biomass, as well as solar water heating; transparent insulation, seasonal heat storage; evaporative ponds in the atria; mirrors at low level in the atria to improve light penetration onto offices and more.[32] Nevertheless, with scientific and technical process, modern materials have come to the building industry, having an effect on the natural environment.

In these technology-dependant societies, we need to be more careful to protect the Earth when choosing building materials. There have been some efforts for protecting the natural environment as well. New buildings will tend to be longer-lasting and lower in energy use. They are likely to be made of simple natural materials such as wood and stone, rather than aluminium and plastic. Internal finishes and furnishings will be based similarly on natural materials and timbers.[33] Some criteria were presented for ecologically sound materials by David Pearson, being;

1. Renewable and abundant, coming from diverse natural sources and whose production has a low impact on the environment.

2. Non-polluting, emitting no harmful vapours, particles, or toxins into the environment, either in manufacture or in use.

3. Energy efficient, using low energy in production transport, and use, and generally coming from local regions. Additionally, they should be good energy conservers with high insulation values that retain heat in winter and keep the home cool in summer.

4. Durable, long lasting, and easy to maintain and repair, tested and tried over several generations - as is the case with natural materials.

5. Equitable and produced via socially fair means, which include good working conditions, fair wages, and equal opportunities. Direct sales from co-operatives in the developing world to consumers in affluent countries should be supported.

6. Low waste and capable of being reused and recycled, thereby saving the vast amounts of energy spent on processing raw materials. Recycled steel, for example, saves more than 70 % of the energy used in manufacturing new steel from primary ore.[34]

In high-rise residential buildings, use of materials are different from traditional houses. For structural safety, fast construction and economical reasons, reinforced concrete is most widely used, consisting of concrete and steel. Bricks are used for the main structure in a few high-rise residential buildings, although most of the buildings need bricks just as a supplement. For the assessment of materials in high-rise apartment buildings, most widely used materials are chosen for the assessment; concrete, steel, brick, timber, insulation materials and glass. While concrete and steel or brick are used for a main structure of a high-rise apartment building, timber, insulation materials and glass are used as a subsidiary. Although the latter are relatively small volumes for high-rise apartments, they are important materials in terms of environmental design. They can help passive design through accepting solar energy or conserving indoor temperatures.

Concrete

Concrete is made by mixing water, sand, gravel or crushed rock and cement. Apart from cement, which has been heated and ground in production, all other materials are taken directly from natural sources. It consumes less energy in its manufacture than most other building materials. It produces few emissions, needs no toxic preservatives and no additional applied protection for fire resistance. Through its lightweight form it possesses good thermal properties with a high proportion of voids, so concrete contributes energy during the building operation. Moreover its thermal capacity makes control of internal climates far easier and can reduce the need for air-conditioning which will reduce energy consumption and CFC emissions. It can also give efficient acoustic insulation.[35] In practical terms, concrete is very flexible for many different roles. It can be relatively durable if long-life is required, and highly attractive if aesthetics are important. These merits are environmentally friendly, like concrete's other natural advantages.[36]

Concrete, however, has some defects such as cracks by shrinkage and contraction. Although it can contain other wastes, concrete itself may be a big volume of waste. It is difficult to recycle or reuse and to destroy, when it reaches to the end of its life.[37] When needing a special purpose such as light-weight or strength, energy content of the concrete increases because of special treatment. However, because of many merits, it is one of the most widely used building materials, especially for high-rise buildings.

The manufacture of cement is one of the early stages in the production of concrete. Cement makes up 10-20 % of the mass of a typical concrete mix and is its most energy-rich component. However, it has less environmental impact when it is used in the finished structure, and over its lifetime, compared to alternative materials.[38]

Other components are all environmentally sound materials, but careful selection of them are required for the environment. Significant energy for transportation can be spent if these come relatively far. Impure materials can cause unexpected defects in the structure. There should be a full environmental assessment for special-purpose concrete, such as high-tension or light-weight types.

Steel

Steel is one of the essential materials for high-rise buildings either in steel-frame structure or in reinforced concrete structure. Although there are many cases with steel-frame for high-rise buildings, it is still rare to have such structures in apartment buildings. Use of steel in high-rise apartments is, therefore, limited to reinforcing rod in reinforced concrete structure. Apart from using reinforcing rod for a main structure, more steel is required for joints, angles, plates, pipes, etc. A merit for steel in building construction is that it requires relatively small volume for sustaining a building compared to other major materials. If carefully designed and installed, it is strong enough to keep buildings safe with small volume. It also has an advantage to be recycled easily when a building is reconstructed.

However, most metals are environmentally destructive in their extraction. They also tend to be highly energy-intensive and polluting in their production, yet there are considerable differences in their damaging effects. Apart from energy-intensive production and polluting in their production, steel has another environmental impact during the manufacturing procedure. For steel production, quite a lot of raw materials are used during the production procedure. The raw materials for the production of iron are iron ore (mainly oxides of iron), coke or charcoal, and limestone. Through heating these materials together in a blast furnace, pig iron is produced. Steel for final use is made by reheating the pig iron to purify it, and adding various materials to make different types of steel. On the process of producing pig iron and steels, enormous energy is required. In Brazil, for example, vast areas of tropical rainforest are destroyed to produce charcoal for pig iron production.[39]

Brick

Bricks were first produced in a sun-baked version about six thousand years ago. They are perhaps the oldest processed building materials. The raw materials come from different basic sources from river and glacial deposits, surface outcrops, and deep underground beneath coal seams. During the procedure, water needs to be driven off through drying before firing. Firing takes place at a temperature between 1600 - 2000 °C, depending on the type of clay used. This is the point at which most environmental damage can be done. In addition, during firing, toxic gases and vapours which are both corrosive and polluting are often produced, depending on the raw materials used. This pollution can be reduced by choosing different raw materials.[40]

Engineering bricks are generally high strength and used where durability is required and/or where greatest resistance to water penetration is needed, such as in inspection chambers. There are the traditional colour ranges of blues, purples and dark reds although the classification of density and strength can be met by ordinary bricks which will be lighter-coloured reds.[41] Concrete bricks are harder, more difficult to cut and less pleasant to handle than clay bricks. They need special care in selection, design and in building, to avoid the cracking of brickwork after construction.[42]

Timber

Wood is the oldest, most traditional building material, but it is still a popular one because of its many advantages. Although it is impossible to use timber as a main structure for high-rise apartments, the amounts of timber used are quite great for auxiliary use such as doors, windows, floor finishes, etc. Timber can be a truly renewable resource, compared with other building materials that must use finite raw materials in their production. Timber is energy-efficient not only for its energy content but also its particularly good insulating properties and enabling timber-frame structures to meet the highest standards of thermal efficiency, when a careful design is accompanied. In addition, timber has a good strength-to-weight ratio and is readily workable. It is a warm, natural material, frequently very attractive in appearance, with a variety of shapes for different requirements.[43]

Although timber is a natural and renewable material, the resources we are using is at such an alarming rate that they may cease to be sustainable.[44] Demand for tropical hardwoods from sustainable sources outstrips supply, and acid rain and the indiscriminate use of chemical fertilisers in the developed countries are damaging vast tracts of woodland. Efforts are needed to restrict the use of tropical hardwoods to limited areas of buildings, such as an entrance hall or boardroom, whilst using alternative materials elsewhere. Alternatives to tropical hardwoods include timber from temperate climates which tend to be produced sustainably. It makes environmental or economic sense to ensure that all timber is produced sustainably, including hardwoods and softwoods from temperate climates.[45] We can help to conserve the diminishing supplies of timber by making better use of existing resources. We can reuse old construction timbers, purchase second-hand furniture, and recycle others.

Insulation

Insulation made from glass are relevant for energy saving. There are two insulants from glass; glass fibre and foam glass. Glass fibre is used as an insulating material made by blowing molten glass out of holes in a fast spinning drum. A similar process is used for making rockwool, in which molten rock is used instead of molten glass. Foam glass is not commonly used because of its high cost. However it is extremely durable and water resistant; this combination makes it relevant when considering the insulation of basements or underground buildings where there is the likelihood of the material remaining wet.[46]

Some insulation materials like rigid urethane, extruded polystyrene and phenolic foams are CFC-blown insulants. They may be found in insulated exterior doors, sprayed insulation for underground pipes, and thermal insulation used in building fabric and service installations, currently having about ten percent by weight of the British insulation market. The emission of CFCs from these materials occurs during manufacture and upon destruction, with slow emission during the lifetime of the foam. Where CFC-blown insulants have been used in existing buildings, it is not usually appropriate to remove them because they are often in an inaccessible location. However, when such insulants are exposed, such as upon re-roofing, the opportunity could be taken to provide an alternative type of insulation and to destroy the CFC-blown foam in a controlled way.[47]

Urea formaldehyde foam is a common form of cavity wall insulation. Unfortunately, formaldehyde vapour arising from this insulation can give rise to a number of symptoms in the building's occupants. In particular, irritation to the throat, nose and eyes after injection of the foam which can, in extreme cases, continue for a number of years. It is also a suspected cause of cancer.[48] In certain situations, mineral fibre insulation, which is a skin irritant, can be replaced with cellulose fibre insulation made from recycled newspapers. This material is made from waste, and has a very low embodied energy content, even compared to the relatively low-energy mineral fibre. But care should be taken because research says that cellulose fibre could be a possible cancer hazard.[49]

Glass

Generally, glass is inexpensive but fragile and breaks easily. Glass consists of silica (sand), sodium oxide (soda), and calcium oxide (lime-stone), with mineral oxides, colorants, and cullet (broken glass). These are melted at a temperature of more than 1500 °C, shaped, and then cooled to prevent crystallisation and cracking. Since glass is made from abundant, natural resources, it is healthy and non polluting. Glass is, however, a poor thermal and noise insulator unless it is double or triple glazed. [50] On the other hand, it is a basic ingredient of solar design, incorporating such features as energy-conserving windows, solar panels and sunspaces. Large areas of glass can admit more daylight into homes reducing dependence on artificial light.

Extraction and manufacturing processes can disfigure the environment, and glass production consumes a lot of energy, as well as creating combustion pollution. On the positive side, glass is easily reused and recycled.[51]

Reuse and Recycling of Building Materials

There are finite supplies of almost all building materials and consequently there are sound environmental reasons for using second-hand and recycled building components wherever possible. Not only will the use of these materials extend the time for which finite supplies will be available, but it will also conserve energy and other resources which would otherwise be consumed in the production of new materials. Obviously, second-hand or recycled products are not always available, but to minimise the environmental impact and cost of building operations there is an obligation to keep up with new developments.[52]

Recycling is one of the fundamental principles of ecology. Every item of waste is a potential input for another use or process. People need to think of all the resources used as part of much more sophisticated and interdependent cyclical systems. Waste is a new phenomenon which has been accepted as quite normal - yet until two centuries ago there was virtually no waste, and waste at those days was biodegradable. At present the quantities of waste that are produced by our society are truly staggering. The building industry provides a terrible example. We have the idea that we can throw something away, but we are learning to our cost that the dustbin is our very own earth.[53]

In the Step 5 of EIAHA, three points are given to the concerning ozone deplition, by looking at CFC blown insulation. Three points are given if insulation is all CFC-free, and no points are given if CFC brown insulation is more then 20 per cent. Another three points are given to the conservation of hardwood in tropical region. If tropical hardwood consists less than 10 per cent of wood supply, three points are given. Two points are alocated to health issues, concerning of asbestos and solvent-base paint free. The remained two points are given to the issue of recycling of building materials. If recycled materials are more than 50 per cent of all materials, two points will be appointed. The value of 50 per cent comes from the 'Environmental Standard' by BRE. If recycled materials are more than 25 per cent of all materials, one points is given. Details are in the Table 4-10 at the end of the chapter.

4-3-2. The Embodied Energy of Building Materials

Energy used for building is vital for the environmental assessment of buildings, both in energy used for operating the building, and the embodied energy of materials.[54] The energy required to make a building includes the energy required to extract, process, transport and assemble the materials of which it is made. Since the 1970s attempts have been made to quantify the embodied energy of a range of different materials, constructions and building types. These studies have suggested that the energy used to make a building can represent many times the energy used by the building in a year of operation.[55] By using less energy content materials, we can contribute in sustaining the globe.

Getting proper values for embodied energy is, though, complicated. Trying to collect and standardise data on embodied energy is difficult, because embodied energy data contains not only energy used for extracting raw materials, their transport to the factory, manufacture and delivery to site, but also maintenance, reuse or final disposal. Repair and maintenance of buildings also requires energy and materials. Another difficult thing is that the values of energy content of materials are different for similar materials, according to varing references. The differences between values from different sources are probably a result of variations in definitions, errors in interpretation and actual differences in the production processes involved. These could also arise from differences in methods and assumptions among the sources of data.[56] Here, collections of many different sources have been made to produce a proper assessment tool for an embodied energy figure in high-rise apartment buildings, assessing each material shown above.

The data used in the following tables are collected from; (1) Robert Vale (2) S P Halliday, (3) Nigel Howard, (4) John West et al., and (5) John N. Connaughton. For (5) John N. Connaughton, the data are collected from other sources.[57] Each table for the individual building material shows the number corresponding to these sources. In the embodied energy value of Nigel Howard(3), first one is delivered energy and second one is primary energy.[58] The mean value of the two is taken when producing indicative value for each materials in this case. The values from John West et al. (4) are indicative values, while they also present the range of embodied energy values. Figures shown in GJ/tonne are converted to KWH/tonne, for better comparison. For comparing the values of embodied energy and CO_2 production of different materials, indicative value for each material is presented based on each table. The values of John West(4) and Nigel Howard(3) will have a strong influence on decision, since they are the most recent values and seem to be produced by careful assessment. The values from them have been given five-fold weight when calculating the indicative values. Since the values are only indicative, they are rounded off to hundreds, except the value of concrete which is too small.

Concrete

For concrete it is relatively easy to calculate the energy consumption involved in producing its raw materials, but an energy audit of concrete in use is more difficult to achieve, because not only are there different types of concrete but also an infinite number of structural layouts.[59] There is some discrepancy among different sources. It is impossible to get exact values, but it is normally said that concrete is the material containing lower embodied energy than most of other building materials.

Table 4-3. Embodied Energy and CO_2 Production of Concrete

Source	Embodied Energy (KWH/tonne)	CO_2 Production (kg/tonne)
(1) Robert Vale	195	
(2) BSRIA	1:3:6 - 275 1:2:4 - 360	
(3) Nigel Howard	178 - 214	135
(4) John West		
(5) John N. Connaughton		

Indicative values for concrete in this research are 226 KWH/tonne for embodied energy and 135 kg/tonne for CO_2 production.[60]

Steel

The energy cost of producing metals from ore is very high, so recycled scrap is considerably useful in reducing energy. Much recycled steel is milled directly into reinforcing bars and therefore appears to have a much lower embodied energy than a structural steel section, which is mostly produced from iron ore.[61] The differences of the value are in the Table 4-4, figuring that recycled steel requires only less than one third of the energy of new steel. The value of other sources probably indicate energy for producing steel from raw materials.

Indicative values for steel are divided into new and recycled, and reinforcing rod (strip) and cast iron (section). Values for embodied energy and CO_2 production are as follows; New reinforcing rod - 9400 KWH/tonne and 3200 kg/tonne; New section -

8900 KWH/tonne and 3200 kg/tonne; Recycled strip - 2800 KWH/tonne and 1800 kg/tonne; Recycled section - 2500 KWH/tonne and 1600 kg/tonne.

Table 4-4. Embodied Energy and CO_2 Production of Steel

Source	Embodied Energy (KWH/tonne)	CO_2 Production (kg/tonne)
(1) Robert Vale		
(2) BSRIA	Steel ; 13200	
(3) Nigel Howard	Reinforcing Rod ; 8160-9667	2903
(4) John West	New Strip ; 9730 New Section ; 8896 Recycled Strip ; 2780 Recycled Section ; 2502	3400 3200 1800 1600
(5) John N. Connaughton	(5-1) 6672 (5-2) 10370 (5-5) 8618	

Brick

Different values in the embodied energy for brick may occur according to the different raw materials used. Most figures are based on the clay brick, which contain much more embodied energy than the cement brick, shown by Nigel Howard(3). The cement brick is used in places where less structural strength is required such as interior walls for separating rooms, whilst the clay brick is used in places needing structural strength. The components of cement bricks are similar to concrete, and the energy content of these is much less than for the others. Engineering brick for high strength and being required durability embodies more energy than others.

Indicative values of embodied energy and CO_2 production for cement bricks are 320 KWH/tonne and 200 kg/tonne. Values for clay bricks are 1100 KWH/tonne and 580 kg/tonne, and 1900 KWH/tonne and 1100 kg/tonne for engineering brick.

Table 4-5. Embodied Energy and CO_2 Production of Brick

Source	Embodied Energy (KWH/tonne)	CO_2 Production (kg/tonne)
(1) Robert Vale	Brickwork ; 1195	
(2) BSRIA	Fletton brick ; 175 Non-fletton brick ; 860 Engineering brick ; 1120	
(3) Nigel Howard	Cement brick ; 289 - 364	203
(4) John West	CK* fletton ; 1390 CK nonfletton ; 1056 CK facing & engineering ; 1807 IK* facing & engineering ; 2780	630 540 920 1400
(5) John N. Connaughton	(5-1) 945 (5-2) 778 (5-3) 1751 (5-5) 862	

* CK ; continuous kiln, IK ; intermittent kiln

Timber

Timber is the only common building material which naturally accumulates carbon as part of the growing process. The complexity of energy inputs for timber makes it more difficult to estimate for than other materials. When timber is used in construction, good information on species and origin, careful design and good preservation may enable use or reuse of timber for centuries before the carbon is released again as CO_2.[62] The complexity of energy calculation makes big differences of embodied energy figures according to the sources. The differences can be more than ten times from one source to another. This happens whether timber is local or imported. There are also different figures between hard and soft wood.

It is very difficult to define indicative values for wood production because the difference of each value is enormous. There are differences of values even within one person's research. Local wood shows even more discrepancy, ranging from 111(Vale) to 1585 (West). The indicative values in this text are; values of embodied energy and CO_2 production for local wood are 750 KWH/tonne and 600 kg/tonne; values for imported soft wood are 2200 KWH/tonne and 1600 kg/tonne; values for imported hard wood are 2700 KWH/tonne and 2000 kg/tonne; values for plywood are 3000 KWH/tonne and 1600 kg/tonne.

Table 4-6. Embodied Energy and CO_2 Production of Timber

Source	Embodied Energy (KWH/tonne)	CO_2 Production (kg/tonne)
(1) Robert Vale	111	
(2) BSRIA	Imported softwood ; 1450 Local airdried ; 200 Local green oak ; 200	
(3) Nigel Howard	Plywood ; 2281-4728 Soft wood ; 1778-3622 Hard wood ; 2486-4411	1589 1857 2416
(4) John West	Imported sawn softwood ; 1946-2502 Indigenous sawn softwood ; 1585 Imported sawn hardwood : 1946-2780 Indigenous sawn hardwood ; 1585	600-1000 710 600-1100 710
(5) John N. Connaughton	(5-1) 1779 (5-2) 640 (5-5) 750	

Insulation

In general, mineral fibre insulants embody substantially less energy and CO_2 emissions than polymeric ones for an equivalent thermal performance. Where resistance to water absorption is required, or where an insulant should be used in thin sections like in the prevention of thermal bridging, the enhanced properties of a high performance polymeric insulant may be justified.[63] Either according to volume (BSRIA) or weight (Howard), the embodied energy value of plastic insulation is shown to be much higher than the others; Mineral wool and glass wool, and plastic insulation materials consequently produce more CO_2 than the others.

Table 4-7. Embodied Energy and CO_2 Production of Insulation

Source	Embodied Energy (KWH/tonne)	CO_2 Production (kg/tonne)
(1) Robert Vale	Mineral fibre insulation ; 3892	
(2) BSRIA	Plastic insulation ; 1125 (KWH/m^3) Mineral wool ; 230 (KWH/m^3) Cellulose insulation ; 133 (KWH/m^3) Woodwool (loose) ; 900 (KWH/m^3)	
(3) Nigel Howard	Plastic insulation ; 24167-38889 Glass wool : 7975-9697 Mineral wool ; 6067-9789	9660 2561 2405
(4) John West	Glass fibre ; 8340 Mineral fibre ; 6672	2500 2200
(5) John N. Connaughton		

Indicative values for insulation materials are divided into plastic insulation, glass fibre and mineral fibre; values for plastic insulation are 32000 KWH/tonne and 9700 kg/tonne; values for glass fibre are 8300 KWH/tonne and 2500 kg/tonne; and values for mineral fibre are 7200 KWH/tonne and 2300 kg/tonne.

Glass

Generally, windows embody surprisingly high energy, exceeding the embodied energy of the gas central heating system. Reduced energy in use as a result of a high performance glazing system recovers the additional embodied energy of manufacture, compared with more common glazing systems, typically within a period of five to eighteen years. [64] Single-glazed wooden frames show lowest for embodied energy, but double-glazing pays for its extra embodied energy in about a year. Some high-performance glazing systems may never pay back the extra embodied energy.[65] Therefore, conventional double glazing appears to be the best compromise between embodied and in-use performance, especially if it is wooden framed.

Table 4-8. Embodied Energy and CO_2 Production of Glass

Source	Embodied Energy (KWH/tonne)		CO_2 Production (kg/tonne)
(1) Robert Vale	6116		
(2) BSRIA	9200		
(3) Nigel Howard	3411-4078		1145
(4) John West	3614		1100
(5) John N. Connaughton	(5-1) 3308 (5-4) 6171	(5-2) 4170 (5-5) 3447	

The glass itself also embodies quite high energy. The values from different sources show big discrepancies. Indicative values of embodied energy is 4000 KWH/tonne and that of CO_2 production for indication is 1100 kg/tonne for glass.

In order to help easy comparison between the values for embodied energy and CO_2 production, indicative values for chosen materials are shown in Table 4-9. These values are not exact, since the processes of producing materials are quite different according to the companies, and it is difficult to calculate values of all process which include extracting raw materials, transportation, manufacturing them into certain forms for building component and construction.

In the EIAHA, six points are allocated to the actual embodied energy value: 6 points will be posted if a building require less than 1,000 KWH energy in one square metre, and no points if the value is more than 2000 KWH per square metre. The remained four points are concern of establishment of embodied energy figure. If there is an establishment of embodied emergy figure, 4 points wil be posted. 2 points will be allocated if there is concerns of energy for building materials without establishment of embodied energy figure. Details are in the Table 4-10 at the end of the chapter.

Table 4-9. Indicative Embodied Energy and CO_2 Production of Chosen Building Materials

Material		Embodied Energy (KWH/tonne)	CO_2 Production (kg/tonne)
Concrete		226	135
Steel	New Reinforcing Rod	9400	3200
	New Section	8900	3200
	Recycled Strip	2800	1800
	Recycled Section	2500	1600
Brick	Cement Brick	320	200
	Clay Brick - Hand Made	1100	580
	Clay Brick - Engineering	1900	1100
Timber	Local	750	600
	Imported Softwood	2200	1600
	Imported Hardwood	2700	2000
	Plywood	3000	1600
Insulation	Plastic Insulation	32000	9700
	Glass Wool	8300	2500
	Mineral Wool	7200	2300
Glass		4000	1100

4-4. Energy Use during Building Occupancy

4-4-1. Heating Installation

Using energy for building operations is another category relevant to the environmental design of buildings. Although there are many activities which require energy such as lighting, cooking and entertainment using electricity, energy use for thermal comfort is the biggest portion in most buildings in most areas, and has great potential to be reduced. Most buildings require certain mechanical equipments to maintain a satisfactory thermal balance. In order to get satisfying thermal comfort, the source of energy which is to be used and the means of distributing the heat derived from that energy into the building should be decided. Although the main criteria involved in this decision are amenity and economy,[66] the importance of environmental issues concerning to heating installations should not be passed over. With a good design for the natural environment and a proper mechanical heating facility for energy efficiency, energy consumption and pollutant production can be reduced.

In most cases, there are constraints in the process of choosing a heat method which limits the range of decisions. Economic factors are especially complicated to figure out. The cost of fuel over the life of the installation are not clear to define and it is difficult to get a solution by averaging the costs over a period of years, except for temporary buildings. The relationship between building and installation life is also important. When many years are required for the changeover, the decision is more difficult and may need speculative assumptions about future fuel costs. In cases where the economic decision is not clear it may be best to assume that economically the possibilities are the same and to base selection on considerations of amenity and the environment. In certain cases, although economic merits exist, alternatives should be considered because of environmental concerns. In the UK, for instance, a house heated by oil might typically produce 30 per cent more carbon dioxide than a similar house heated with natural gas, to get affordable and satisfactory thermal conditions, although the price of oil is cheaper.[67]

Energy for heating is commonly derived from various solid fuels, oil, gas and electricity. It is also possible to take the sun's energy or to extract heat from the air or a river. Economic decisions about fuel selection are difficult, partly because of uncertainty about fuel prices and partly because problems of conservation, supply and ecology must now be kept in mind. It is clear, however, that in the future, whatever the problems are, much closer attention will have to be taken into account in the design of buildings to economise on fuel consumption.

Traditionally fuel could be moved into buildings but the controlled distribution of heat was difficult, consequently the fuel was burnt in the space where heating was required and the heat emitted directly to the room. A comfortable thermal condition was gained by controlling the rate of combustion. This traditional type of open fire is now rarely installed except for decorative purposes. A range of specially designed fires and stoves is now available, which will burn smokeless fuels and operate with relatively little trouble. Recent technical developments have greatly improved both the thermal and the smoke emission performance of solid fuel appliances even at the domestic level. New techniques have also been applied to boilers which enable bituminous coal to be employed and provide very high efficiency.[68] The direct heaters can be categorised into oil, gas and electric heaters according to the source of the fuel.

Over the last 100 years effective methods of transmitting heat around buildings have been developed. They enable fuel to be converted to heat at a central point, thereby reducing the number of flues required to one, eliminating the need to distribute fuel and simplifying maintenance and control. In new buildings, including houses, this type of central installation is now almost universal.[69]

4-4-2. Central Heating and District Heating

Central heating is 'the heating of buildings using one energy-efficient central boiler and pumps to transfer heat to radiators by hot water in a pipe circuit.'[70] Although central heating installation has been popular and has developed since the last century, the origin of the idea can be found a long time ago. The first application of central heating, where the source of heat is located some distance away from the area where heat is required, is credited to the Lacedaemonians of Greece, who constructed a temple in Ephesus in about 350 B.C. In this system, hot gases were passed through conduits built into the floor. Around the time of 80 B.C., the Romans, as the greatest colonisers, developed the use of fire to warm themselves and their buildings, as they advanced further northwards. Steam heating as a modern type of central heating first appeared in England in 1745, proposed by William Cook, followed by James Watt and Matthew Boulton using steam to heat their rooms indirectly. The idea of replacing a directly acting working substance with one that acts indirectly and is recirculated within the system must be regarded as a major advance in the technique of warming the built environment. This first successful use of hot water in this way was by John Evelyn in 1675.[71]

A central heating system basically consists of a boiler, furnace or mechanisms for the production of heat from fuel, a system of pipes or ducts holding a heat medium, leading to heat emitters in the various rooms or parts of the building, and subsequently returning to the boiler.[72] Fuel is converted to heat in a central plant and the heat is then distributed around the building by a heat transfer medium. Water is the most efficient medium and most widely used, except in some circumstances when water cannot be used because pipes may be subject to freezing. The use of low-pressure hot water for space heating in the built environment is currently the most popular option for the majority of developments.[73] The average flow temperature of low pressure hot water heating installations is usually about 77 °C, but the temperature can be increased to around 175 to 230 °C when the boiling point of water is increased by placing the whole installation under pressure. The system using high-pressure hot water requires smaller pipes, so is considerably economical in the transfer of heat over long distances. However, in this system, the boiler, heat-emitting appliances and pipework have to be able to resist the high pressures, stringent safety precautions are necessary and special consideration must be given to pipe expansion. These factors result in substantial installation costs, and this system has been limited to large buildings or district heating systems in the past. Steam or air can also be used as a heat transfer medium, although they are less popular than water.[74]

In distribution systems, pipes are used for delivering heat from heat generator to the place where heat is emitted. With very simple systems a single-pipe distribution arrangement may be employed for economy. It is possible to obtain some of the benefits by using a two-pipe arrangement for main distribution, but in serving groups of radiators from a single pipe.[75]

The idea of central heating can be extended from the level of a single building to a town level. Buildings in a certain district, town or city can get heat sources from one heating installation using pipes as distributors. City-wide community heating schemes, fuelled by gas, coal and other fuels, are emerging as efficient and clean methods of providing heat and power to both housing and city-centre buildings.[76] This system is called district heating, and defines as 'a method of heating houses or flats in one part of a town from a central supply of heat.' [77]

A district heating system consists of four main components: heating production units, a heat distribution network, building substations and building installations. Heat production units can be one of or a combination of 'heating-only' plants, combined heat and power production plants, refuse incineration plants, or waste heat recovery plants from industry or from geothermal sources. These could also involve auxiliary heating units for peaking and standby purposes. A heat distribution network can be a series of substations with a secondary distribution network.[78] These two components, production and distribution, typically belong to the field of the producers. There has been much work done to produce heat efficiently and to design distribution networks economically. [79]

The urban district heating systems radically decrease air pollution. The source of emissions of dust and gases are localised, built within a proper distance from densely populated town districts. There is the possibility of using highly efficient dust extractors to clean the flue gases and the construction of extra tall chimneys can help disperse the flue gases which allow for a significant decrease of sulphur dioxide concentration and of dust fall per square kilometre of a built-up area.[80] The combustion process can be closely monitored so that less smoke is produced. Besides decreasing regional air pollution, the district heating systems have certain advantages. Larger boilers can be operated at a higher thermal efficiency. The choice of an energy source is widened, making it possible to use oil, coal, gas, or methane obtained from a sewage treatment plant or a waste incinerator. Waste heat may be used from the condensing cycle used in power stations, from the exhaust of gas turbines, or from a geothermal energy source. A multi-fuel facility can be adjusted to any variation in energy costs, and be used to counteract fluctuations in supply. The schemes are also less labour-intensive than when the plant is dispersed over separate sites.[81]

In spite of these advantages, there are some disadvantages which cause difficulties in development. The amount of detailed planning requires the involvement of professionals across many disciplines from the start of the scheme. In a large development there is always a chance that any errors made in the design or execution of the scheme could be repeated many times, making subsequent attempts to rectify them very costly in terms of both finance and human resources. This can adversely affect designers and increase their professional indemnity insurance.[82] The central problem of district heating is, however, not technical but social. There is a wide variety of economic, behavioural, organisational and political obstacles to the adoption of such energy conservation technologies. It turns out that in many countries the organisation of the energy utilities in particular is detrimental to the broad penetration of district heating. The difference of interests at an institutional level has sometimes reduced the rapid spread of district heating. Switching to a new heat supply system in a fully fledged network of gas or electricity, would imply very substantial depreciation costs with regard to the replaced network as well as the heating systems of each dwelling. In addition to these barriers, existing tariff schemes can create an unattractive financial context for the development of district heating systems.[83]

When a system is installed in a building, careful consideration is required. One coherent and complex system is created when connecting a building to a district heating system. Optimisation of this system is not obtained by optimisation of the parts separately. To operate the whole system efficiently, the production and distribution parts should be carefully and mutually matched with the building installation. This requires close co-operation of designers from both sides. The connecting station, as the interface between producers and consumers, can play an important role in this process.[84]

District heating is not always cheaper to install than other forms of heating, but it has an economic advantage over other forms of heating. Compared to early district heating schemes requiring extensive groundwork, heat distribution systems are now much cheaper and easier to install. The latest district heating schemes have reduced overall capital costs, simplified pipe system laying, and achieve even higher overall reliability and improved economy of operation.[85]

By using waste heat, the same amount of final energy used can be reached with less primary energy and at lower environmental costs. As heating sources, combined heat and power (CHP) stations are usually used for district heating. The idea of CHP is relatively simple, and the economic feasibility of CHP technologies depends on the level of fuel to be used by CHP companies.[86] Engine-driven generators produce electricity with large quantities of heat as a by-product. CHP generators use the engines' waste to warm buildings or for industrial processes. Thus CHP generators easily achieve a much higher overall thermal efficiency than conventional condensing power stations which dump their surplus heat in tidal estuaries or in cooling towers. Therefore, the overall energy savings from district heating are significant.[87] The overall energy efficiency of electricity generation can increase from around the 34 percent achieved in conventional power stations to as much as 80 percent or more in the CHP power system. CHP plant can be of any size ranging from tens of kilowatts to many megawatts, and it can run on virtually any fuel. The beauty of the system is that it can match pretty well with any requirement.[88]

CHP units can run unattended for thousands of hours a year, monitored from a distance in case any attention is needed. CHP systems for buildings are clearly more complicated than normal boiler plants with electricity taken from the mains, but given competent planning and installation modern CHP systems perform as reliably as other plants of equal complexity.[89] The increasing importance attached to environmental and energy efficiency issues has also benefited CHP. The government's own research, for instance, has indicated that the efficiency benefits of CHP could reduce UK greenhouse gas emission by some 15%.[90] British government, as well as that many other countries, support in promoting CHP as one of the major contributors to meet the CO_2 reduction commitment made at Rio. The funding from the Energy Efficiency Office have helped to establish CHP as a mainstream alternative to conventional energy supply.[91]

When CHP is installed in a building, requirements for heating and electricity should be investigated. Results from the individual dwellings show that the demand for electricity varies widely throughout the day, with high peak loads lasting only a few minutes and long periods of the day when demand was very low or even zero. However, where individual dwellings can be grouped together the demand is likely to be less peaky, and blocks of flats are more suitable for the range of CHP machines currently available. Although the total demand for heat over a day is greater than the total heat output from a CHP machine sized to maximise electricity production, the instantaneous demand may not coincide. For a winter day having a mean temperature of 0°C, the heat given off by both the modulating and fixed-output CHP units is always less than the space heating requirements throughout the day and any heat generated can always be used.[92]

4-4-3. Underfloor Heating

Types of heating installations in buildings are various. Direct heaters, which are installed in the room where heating is needed, are not popular, except for decoration in modern housing as mentioned before. Most heating emitters are at some distance from their heat generators. The heat emitters can stand in the form of heat radiators besides walls or can be installed under the floor. The latter is called underfloor heating and it dates back to Roman times when 'their "hypocaust" had a stone floor on small pillars and hollow walls, warmed by smoke from fires below.'[93]

The heat emitter for underfloor heating uses cables using electricity or pipes with hot water inside. In electric underfloor heating, there is a thicker screed than normal in which a grid of cables is laid. The screed is then heated during the off-peak period and will give off its heat during the following day. The design of electric underfloor heating must take into account not only adequate thermal capacity but also the limitation of the surface temperature to an acceptable value for comfort. The main control of this type of heating is by time-switch which limits the period of electrical input to off-peak periods. In addition to the time switch thermostatic control is necessary. For small buildings a simple room thermostat may suffice while for larger installations controls that take account of weather will be desirable and it may also be necessary to divide the building into zones for control purposes.[94] The construction and insulation details of the screeds for hot water underfloor heating are similar to those for electric underfloor heating, but using copper (or plastic) pipes containing hot water. Care must be taken that the rooms where this type of heating is used are sufficiently high to ensure comfort for the users of the building.[95]

Typically the underfloor heating system uses low-pressure pumped water at a mean temperature of around 40°C, with an approximate overall temperature drop of 5°C. When underfloor heating of any kind is used, it provides an overall feeling of warmth, owing to the even spread of heat, of which approximately 50 percent is radiant, emanating from the whole floor, at a surface temperature between 21°C to 29°C. Because of this high radiation component, comfort conditions are achieved at air temperatures that are about 2°C lower than the values needed with warm air heating, so that with suitable controls it is possible to use less fuel for the same effect. The system also produces a minimal vertical temperature gradient. Underfloor heating is suitable for areas where it is considered unsatisfactory to take up space with conventional emitters or ducts.[96]

By the middle of the 1980s, interest in the technique continued and the major weaknesses of the early electrical resistance and metal pipe systems were eventually overcome by the development of suitable plastic pipes. The flexibility and excellent corrosion resistance of plastics, together with improved standards of insulation, made it possible for a new generation of underfloor heating systems to capture an ever increasing market share on the European mainland throughout the 1970s and the 1980s. Underfloor heating in the middle of the 1980s accounted for a very significant proportion of total sales in all the leading European countries and its share will still be growing fast.[97]

Step 5 and Step 6 of the EIAHA are about heating system. Step 5 concerns heating mode and fuel type. District heating with CHP instalment, which is one of the most energy-efficient heating mode, will get 5 points in the assessment; while district heating without CHP will get 4 points. Five more points are allocated for fuel type, where less environmental impact fuel such as garbage and natural gas will get more points. Step 6 concerns about the operation of heating system. There are five items, each of them has two points. These are easy control of the system, billing system through efficient metering, complains, theirmal equality between floors and comfortability.

4-5. Long-term Analysis of Management and Maintenance

4-5-1. The Building Life

Even after completion of construction, a building has the potential to affect the environment. Buildings cannot stand with the same condition forever, and finally they come to their final stage, demolition point. Demolition and reconstruction again have serious effects on the environment, by using massive amounts of raw materials and producing waste. Good maintenance management with proper long-term repair plans and adequate financial arrangements is required for longer lifespans. The process of repair also has the potential to degrade the environment. Demolition, as the final stage of a building's life, can be a starting point for a new life, if there will be a new building on the same site. Reuse of materials from old buildings when new development is launched plays an essential part in preserving raw materials.

A longer life for buildings with easy maintenance can be expected if they are designed carefully. It is highly desirable, but not possible to produce buildings that do not need maintenance, although much can be done at the design stage to reduce the amount of subsequent maintenance works. Case studies show that about 1/3 of the maintenance work could have been easily avoided if sufficient care had been taken at the design stage and during construction.[98] During the design stage, future requirements should be counted as well. The constant need to provide new or modernised housing is due to a number of factors. One of the most important future requirement involves changes in population and the deterioration of the existing housing stock. Rehabilitation of existing structurally sound housing is usually a much more cost effective and environmentally sound option than demolition and building a new. Generally, the cost of renovating an existing house will be half that of providing a new one.[99]

The importance of management, however, is as big as the design of the building. Alex Henney argued in the Architect's Journal[100] that 'a large part of the stock should be transferred in blocks of about 500-2000 dwellings to "housing management trusts" in charge of managing and improving housing.' He also suggested that housing management could be achieved by outright sale to a private company, if councils are satisfied with the arrangements.

One of the difficult things for housing management is that no single formula can be applied to all blocks. Although the target for managing a building may be shared to achieve a longer life without reducing the quality of it, the physical components of the building and the socio-cultural issues surrounding it differ which requires different approaches for each building, especially for housing. Consultation with tenants or co-operative management are certainly required for successful public housing estates. It is not so simple, however, because every tenant has his own opinion for his home which prevents the making of a single conclusion for better management. Ruth Owens quoted the idea of Tricia Zipfel of the DOE's Priority Estates Project that 'co-operations cannot be extended to cover all problem estates, because not all tenants want to devote all their energies to managing their housing.'[101]

It is difficult to say how long should a building last. If concerned about the life of concrete, high-rise apartments may last about 60 years. In EIAHA, if life expectation of an apartment building is more than 60 years, which is almost as long as its physical life, 4 points will be allocated. If the life are expected less than 29 years, which is just half of life expectancy for long-life building, there is no point. Apart from life expectancy, 3 points are allocated ro the consideration of easy repair, and the other 3 points are allocated to the social aspect of building life.

4-5-2. Maintenance Plan

Building maintenance is defined as work undertaken in order to keep, restore or improve every facility, i.e., every part of a building, its services and surroundings, to a currently accepted standard and to sustain the utility and value of the facility. The maintenance budgets are prepared using the master action plan based on the building inspections and information from the previous year's building operational expenses. It is necessary to have the information about the anticipated life span of major components used in buildings. A reserve fund needs to be set up so that funds for retrofitting or replacement will be available when needed. For many materials and components, maintenance work or replacement needs to be done as soon as the damages become evident if a small defect leading to a complete failure would be avoided.[102]

The need to maintain the existing facilities is obvious. Under-maintaining a facility involves high life-cycle cost, whereas over-maintaining the facility for short term needs may result in higher production costs making it less competitive. Record keeping on maintenance history will be helpful in identifying the nature and frequency of occurrence of the problem and provides statistical evaluation on the performance and system reliability. The supply of materials for maintenance and rehabilitation works may be required only in small quantities and distributed over a number of different sites, which results in increased transportation and material costs. One way of reducing the material cost is through use of locally available materials and recycled or waste materials for rehabilitation works. The upkeep on the maintenance history and audit reports on the performance - before and after maintenance, spares used and costs - will provide valuable information on the cost of rehabilitation or modification of a facility which might come up at a future date.[103]

In the last step of EIAHA, management with proper maintenance plan will be assessed. The step 8 deals with the establishment of management system (2 points), fund for maintenance (4 points) and proper repair plan (4 points).

4-6. Summary of the Credit Points of EIAHA

There are 8 steps in the assessment (4 main areas containing 2 sub-areas each), which have been mainly described to a large extent in previous sections. The assessment tool uses a credit system, with each step setting a certain amount of credits - 10 points. If the credits obtained are 8 points or more, it will categorised to 'Good'; between 5 and 7 points, 'Medium'; and 4 points or less, 'Bad'. A summary of the credit points is set out in Table 4-10. The total 80 credit points are available and over 64 points will be 'Good', between 40 and 64 points will be 'Medium' and less than 39 points will be 'Bad'. However, the attemption here is not giving total credit points to asses high-rise apartments, but looking at the balance of each step. Therefore, although the total points abtained are the same, the environmental impact will be different according to the differences of points among steps.

Table 4-10. Credit Points of the EIAHA

Item	Credit
Step 1. Passive Solar Design	
Orientation	South - 4 points. South-East, South-west - 3 points, East, West - 2 points, North-East, North-West - 1 point, North - 0 point
Room Arrangement	Main rooms facing South, South-east, or South-west - 1 Point Others - 0
Balcony&Sun Space	Balcony with sunspace window preinstalled - 5 Points Balcony with sunspace, window installed later - 3 Points Balcony with sunspace - 2 Points Balcony only - 1 Points
Step 2. Insulation and Ventilation	
Wall Insulation (U-value)	Less than 0.4 W/m2K - 4 Points Between 0.41-0.45 - 3 Point Between 0.46-0.50 - 2 Points Between 0.51-0.55 - 1 Point More than 0.56 - 0 Point
Window glazing	Double Glazing - 2 Points Single Glazing - 0 Point
Thermal break & Condensation	Outer wall insulation - 1 Point Condensation-free - 1 Point
Ventilation	Cross Ventilation - 2 Points
Step 3. Building Materials - Ecological and Health	
Insulation	All CFC-free insulation - 3 Points CFC blown insulation less than 10 percent - 2 Points CFC-blown insulation between 11-20 Percent - 1 Points Otherwise - 0 Point
Wood	Tropical Hardwood less than 10 percent - 3 Points Tropical Hardwood between 11-20 percent - 2 Points Tropical Hardwood between 21-40 percent - 1 Points Otherwise - 0 Point
Health	Asbestos free - 1 Point Solvent-based paint free - 1 Point
Recycled Materials	Recycled materials are more than 50 % - 2 Points Recycled materials are more than 25 % - 1 Points

Table 4-10 continued

Item	Credit
Step 4. Materials' Embodied Energy	
Concern	Establishment of Embodied Energy Figure - 4 Points Concern of Energy Saving for Materials - 2 Points
Embodied Energy value	Less than 1,000 KWH/m^2 - 6 Points Between 1,001-1,200 KWH/m^2 - 5 Points Between 1,201-1,400 KWH/m^2 - 4 Points Between 1,401-1600 KWH/m^2 - 3 Points Between 1601-1,800 KWH/m^2 - 2 Points Between 1,801-2,000 KWH/m^2 - 1 Point More than 2,000 KWH/m^2 - 0 point
Step 5. Heating Mode and Fuel Type	
Heating Mode	District Heating with CHP instalment - 5 Points District Heating without CHP instalment - 4 Points Central Heating - 3 Points Individual Boiler - 1 Point Others (fireplace, low-efficient heating mode) - 0 point
Main Fuel Type (more than 90 % of fuel used)	Gas and Garbage - 5 Points Gas, Oil and Garbage - 4 Points Oil and Gas - 3 Points Oil, Gas and Coal - 2 Points Oil and Coal - 1 Point Coal - 0 point
Step 6. Operation of Heating System	
Control	Easy control of the system - 2 Points
Metering	Well established billing system - 2 Points
Complaints	No complaints from residents about operation - 2 Points, Less than 5 percent complaints - 1 Point
Equality	Thermal equality between floors - 2 Points
Comfortability	Even room temperature through underfloor heating - 2 Points Efficient distribution of radiators - 1 Point

Table 4-10 continued

Item	Credit
Step 7. Building life	
Life Expectation	More than 60 years - 4 points Between 50 and 59 years - 3 points Between 40 and 49 years - 2 points Between 30 and 39 years - 1 point Less than 29 years - 0 point
Consideration of Easy Repair	Easy Separation of Pipes - 2 point (One for heating, one for others) Easy Testable for Main Structure - 1 point
Social Aspect of building life	Resident's life expectation of building over 50 years - 1 point No intention of redevelopment by construction companies within 50 years- 1 point Governmental encouragement of building life over 50 years- 1 point
Step 8. Management System	
Establishment	Establishment of management system : 2 Points
Fund for maintenance	Enough for Long-term Repair plan : 4 Points Established but not enough : 2 Points Not established : 0 Points
Repair plan	Life-time repair plan : 2 Points
Short term Repair	Year-by-year repair plan : 2 Points

Summary of the Chapter

This chapter has looked at a selected number of factors which are taken to be indicators of environmental impact for high-rise apartments, leading to organising an assessment method, the EIAHA. The EIAHA started with the design stage which dealt with passive solar design. A well-designed high-rise apartment can reduce the heating and cooling load, and by using the sun for energy and installing proper insulants we can reduce the demands on mechanical heating systems. Proper insulants also have the effect of creating comfortable thermal conditions in summer, if well-designed ventilation accompanies them.

The EIAHA goes on to the construction stage, where construction materials are deeply researched both in terms of ecology and embodied energy. The target for less-energy consumption can also be accomplished by carefully choosing building materials, as materials themselves embody energy during extraction, delivery and manufacture. The embodied energy of building materials is difficult to calculate, because there are many discrepancies such as the process of manufacturing and the distance from raw materials. If energy requirements for life-time maintenance and final disposal are included, calculating the figure for the embodied energy of building materials becomes more complicated.

There is further potential to reduce energy through choosing on efficient heating mode. Well-designed heating systems can save fuel consumption, without reducing or even improving thermal comfort. If carefully designed, the district heating mode can save enormous amounts of energy compared to conventional heating or the central heating mode. If the district heating mode takes combined heat and power (CHP), further savings are gained by using waste heat during electricity generation. However, thorough investigation of capital costs and careful design for safe operating are required to avoid any side effects.

Finally, long-life apartment buildings through proper maintenance management are preferable for the environment. An ideal building life cannot be identified, but every effort to extend the life of a building is useful, if its condition is maintained. Additional costs for proper maintenance will be much less than the costs for destruction and rebuilding. Longer life buildings are also more environmentally friendly since they can save on raw materials for reconstruction and generate less waste.

The credit points and grade of EIAHA were summarised in the last part of this chapter, and the EIAHA is now applied to the assessment of high-rise apartment developments in Korea (Chapter 5) and in the UK, Hong Kong and Singapore (Chapter 6). Comparisons of developments in different countries will be shown at the end of Chapter 6 after looking at each development. When compared, the EIAHA, which comprising four main elements with two steps each, is used.

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(195 + 275 + 360 + 196 x 5) / 8 = 226.25 $\rightarrow$ 226

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Chapter 5.

Application of EIAHA to Current Korean High-Rise Apartments

The demand for apartments in Korea has been a major issue because the housing spread rate[1] remains less than 85 percent despite the increase in housing unit numbers since the end of the 1980s, as described in Chapter 3. It is no wonder that the Government has pushed construction companies to provide as many housing units as possible, paying little due regard to the quality of the units. Recently, around 500,000 apartment units are being built each year, and apartment developments are one of the biggest businesses for construction companies in Korea. Approaching the twenty-first century, important concerns now are not only the number of units but also the need to improve living standards, as well as to meet international environmental agreements. A proper assessment of the current situation will be vital if improved conditions are to be achieved. Therefore, there is a special need to understand sustainable apartment development.

This present chapter applies the EIAHA described in Chapter 4 to the current development of high-rise apartments in Korea. Better environments cannot be achieved through solving a single problem, since many complicated elements are interrelated with each other, and there are many barriers and restrictions to the achievement of good living conditions. The investigations provide the foundation for proposals related to a better environment later in Chapter 7, whilst Chapter 6 draws upon the experience of other countries.

The assessment mainly applies to the five apartment estates in Pundang New Town which were described in outline in Chapter 3 (also shown in Appendix). Two of them are built by the Korea National Housing Corporation (KNHC) and the rest by private companies. Most of the design and construction methods in Korean apartment developments are quite similar, so it is sufficient to focus on a few estates as a representative of the whole apartment construction industry. These five estates, which were developed in the late 1980s and early 1990s, are appropriate examples for assessing the trends of current apartment developments in Korea. Earlier parts of each section describe general description of current trends of appartment construction according to the assessment order, whilst the last part of each section summarises the result of the assessment of above five apartment estates.

5-1. The Passive Design Element

5-1-1. Passive Solar Design

From the analysis of the regional climate, which is shown in Chapter 2, design priorities in Seoul should be to keep the heat in during the winter, using natural ventilation for summer cooling, letting the winter sun in, protecting from the summer sun, and avoiding creating additional humidity during the summer.[2]

Most apartment buildings in Korea have a proper orientation for passive solar heat. Main living areas of them tend to face south, south east or south west, according to the site. The master plan of each estate in Pundang is no exception. Since Pundang is a planned city, each land block has a guide for a plan made by the Government, who recommend how to achieve a variety of scenery, the height and orientation of apartment buildings on each site. According to this recommendation, each construction company designed the masterplan of the given estate.

Site plans of apartment estates depend on the shape of each site. As shown in Appendix 5, the shape and size of estates are various. Most of them have a rectangular shape with a south - north axis or southeast - northwest axis, while others have an irregular shape. Each unit has access to the sunshine in the main bedrooms and living rooms. These rooms are facing south, south-east, south-west or east according to the building orientation. It is not easy to have enough distance between buildings to allow enough sunshine in for lower storeys, but designers try to take account of the distance. In south - north axis sites, most buildings are facing south with a few to the east or west, while in northwest - southeast axis sites, all buildings are facing either south east or south west. In irregular shaped sites, buildings tend to face south, with some of them facing south-east or south-west, according to the shape of the site.

There are two main types of unit arrangements in Korean apartment buildings. One type, called a corridor type, has a long corridor on each floor sharing one of more lift(s) and staircase(s). The other has (a) lift(s) with a stair only for two units of each floor and is called the staircase type. For the first, a corridor is located in the north, north-east or north-west of the buildings. Living rooms and main bedrooms are located at the other side. Since most units of the corridor type are quite small, all the rooms are packed together. In some bigger units, living-dining-kitchen areas are open, which is good for ventilation in summer. Balcony spaces in front of living rooms or main bed rooms have a greenhouse role in winter. In the second type, which has its own stair and lift for two units of each floor, a staircase with (a) lift(s) is located in the middle of the two units. The living rooms and main bedrooms are also in the south-facing of the building with balcony areas. There are also balconies in the north part, which have the effect of a buffer zone for mediating the difference between indoor and outdoor temperatures. There is an open plan through living room and dining-kitchen, for good ventilation in summer. The room arrangement of apartment units are shown in Appendix 5. The numbers shown above each unit plan are the size of each unit in PY (pyeong), and unit sizes vary from 12 to 79 PY (40 to 282 m^2).

Most apartment units have balconies in both side of the units. To give a buffer space between the indoor and outdoor areas, the Government encouraged the use of balconies by providing these spaces as a tax free zone. Property tax (council tax) is taken according to the private area, but the 1.5 metre width of balconies of each unit is not calculated for the area. Whether this space is intended to be made originally for insulation or not, the 1.5 metre of balcony area on the south-facing wall is especially important for solar design. It is wide enough to avoid the summer sun entering inside (normally the living room or the main bedroom), and narrow enough for the winter sun to enter the living area through this balcony area. Double glazed windows in each living area located both sides of the balcony help keep heat inside the building in winter. This space will be open in summer time for natural ventilation, having a role to prevent summer sun entering into the living areas. Some residents make these spaces into private gardens.

5-1-2. Thermal Insulation

The thickness of insulation material and the minimum requirement of K-value[3] are restricted by building regulations according to the region.[4] Regulation of K-value is shown in Table 5-1. For ease of understanding, U-values are calculated and shown in brackets.

Table 5-1. Regulation of K-value (U-value) in Buildings in Korea

Unit : $kcal/m^2\ h\ °C$ (W/m^2K)

Area	Central Region	Southern Region	Cheju Island
Outer wall, Bottom Floor	0.5 or less (0.58)	0.65 or less (0.76)	1.0 or less (1.16)
Roof	0.35 or less (0.41)	0.45 or less (0.52)	0.65 or less (0.76)
Side wall in Apartment building	0.4 or less (0.47)	0.6 or less (0.70)	0.7 or less (0.81)
Windows	2.9 or less (3.37)	3.1 or less (3.60)	5.0 or less (5.81)

Source : *Architecture Law* (building regulation), the Government of Korea

* Look at Table 6-1 for comparing U-values of Dwelling Building in Britain

The floor area, which has an under-floor heating system with mass of concrete, can keep heat while heating is provided. Walls do not have such an effect, and they are easily overheated in summer leading to very uncomfortable summer nights. Insulation materials in walls and roofs are installed in the inner part of the concrete volume. Parts of walls and ceilings have special treatment for preventing condensation, because of the humidity in summer and big temperature differences between indoor and outdoor space in winter. More consolidation of the K-value is found for apartment buildings than other buildings in the table. Front and back walls, in which balcony areas are usually located, follow the regulations as other buildings, but side walls require lower K-value. One of the reasons is to provide similar thermal conditions for units which are located at the end of each floor. To help designers accomplish the necessary K-values, thickness of insulation materials in walls, ground floors, and roofs are indicated by the Government. They are shown in Table 5-2. Insulation materials used here are glass wool, mineral wool and expandable polystyrene.

Table 5-2. Regulation of Thickness of Insulation

Unit: mm

	Central Region	Southern Region	Cheju Island
Outer wall, Bottom Floor	50 or more	40 or more	30 or more
Roof	80 or more	60 or more	40 or more
Side wall in Apartment building	70 or more	50 or more	40 or more

Source: *Architecture Law* (building regulation), the Government of Korea

Most windows are double glazed for better thermal performance. Construction companies do not usually provide windows outside the balcony area, but dwellers tend to put windows with single glazed glasses even before they move in. Research shows that there is a significant reduction of fuel bill around 10 to 15 percent by installing glasses outside balcony area.[5] Some construction companies provide windows in the balcony as an option. Components of a wall, a roof, a floor and a window in an apartment building built by KNHC are shown in Figure 5-1.

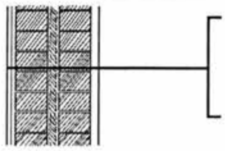
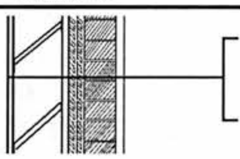
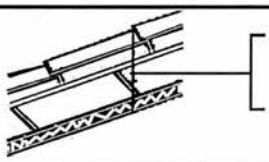
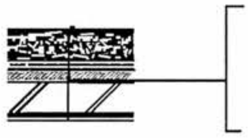
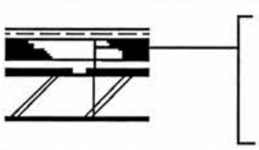
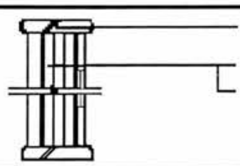
Item		Component
Wall Front and Back		Plaster Board : 9mm + 9mm Cement Brick : 90 mm Airspace : 60 mm (inside glass fibre) Cement Brick : 90 mm Mortar : 24 mm
Wall Side		Concrete : 150 mm Airspace : 80 mm (inside two fold insulation 70 mm) Cement Brick : 90 mm Mortar : 18 mm
Roof pitch		Roof Tile Waterproof Mortar : 10 mm Concrete Slab : 120 mm Insulation : 80 mm
Roof flat		Concrete : 80 mm Polyethylene : 0.03 mm + 0.03 mm Insulation : 60 mm Asphalt waterproof Concrete : 120 mm Insulation: 20 mm Plaster Board : 7 mm
Floor Upperfloor		Cement Screed : 30 mm Gravel : 70 mm Mortar : 30 mm Insulation : 20 mm Concrete : 120 mm
Floor Groundfloor		Cement Screed : 30 mm Gravel : 70 mm Mortar : 30 mm Insulation : 20 mm Concrete : 120 mm Insulation : 40 mm Fireproof Insulant : 10 mm
Window		Concrete Plastic Window Flame Wood Window Flame

Figure 5-1. Components of Walls, Roofs, Floors and Windows in Apartment Buildings built by KNHC.

5-1-3. Assessment of Passive Design

Passive designs of apartment buildings in five estates are almost identical. The orientation is strongly related to the shape of each estate with the preferance of facing to south, south-east or south-west. Insulants are installed at the minimum requirement of the regulation. Cross-ventilation is considered in the unit plan avoiding overheating in hot-humid summers. The credit points according to the EIAHA in Table 4-10 for five estates in Pundang are summarised in Table 5-3.

Table 5-3. Summary of Credit Points for Passive Design

Item (Maximum Points)	Credit				
Apartment Estate	A	B	C	D	E
Step 1. Passive Solar Design					
Orientation (4)	3	4	3	3	4
Room Arrangement (1)	1	1	1	1	1
Balcony&Sun Space (5)	3	3	3	3	3
Total Points (10)	7	8	7	7	8
Grade	Medium	Good	Medium	Medium	Good
Step 2. Insulation and Ventilation					
Wall Insulation (4)	2	2	2	2	2
Window (2)	2	2	2	2	2
Condensation (2)	1	1	1	1	1
Ventilation (2)	2	2	2	2	2
Total Points (10)	7	7	7	7	7
Grade	Medium	Medium	Medium	Medium	Medium

Passive design is generally well established in the case of orientation and room arrangement, but there is a space of improvement in the area of installation of glasses outside balcony area, which can reduce further energy requirement. There is a need to improve the standard of insulation (U-value) for acquiring a proper thermal insulation.

Insulation is usually installed inside of the structure, which may cause thermal break, so change of the insulants on the outside wall is suggested.

5-2. Building Materials

5-2-1. Construction Method and Use of Building Materials

Most apartment buildings in Korea are built in the method of wall-type structure mainly using reinforced concrete. Walls and floors are used as a structure rather than beams and columns. Construction only takes less than two years for a fifteen-storey apartment building from starting work to finishing, including decoration, and that of a thirty-storey block takes less than three years. The time for making a whole frame is usually less than one year for a fifteen-storey building. Kitchens and bathrooms are usually fitted and use tiles on walls, ceilings and floors, and bedrooms and living rooms are finished with wall papers and floor papers[6] by the construction companies. Furniture in living rooms and kitchen-dining rooms tends to be provided by construction companies. The completion of construction means a ready-to-move-in condition. In most buildings, in-situ reinforced concrete is used, while the use of pre-fabricated concrete is increasing.

To meet the massive requirement of housing, the government pushes the construction companies to make many apartment buildings in a short time while suppressing the price of apartment units. Construction companies, especially small companies, pressed by the given construction period and by money, have ignored the quality of buildings. These trends in the late 1980s and early 1990s became reasons for a sequence of construction disasters such as the collapse of the Sampoong department store and the Songsu Bridge. Even though there has been no collapse of apartment buildings recently, people living in high-rise apartments feel in danger, especially in those apartments built during the above period. After the collapse of the Sampoong department store in July 1995, building owners and high-rise apartment residents try to check the safety of their buildings. The middle of the 1990s will turn out to be a turning point for construction in Korea, giving priority to quality over quantity.

Since Korea once had plenty of good quality cement, sand and gravel, concrete structures had also been one of the easiest and cheapest methods of construction. However, extensive use of sand from rivers and gravel from mountain areas has caused an interruption in the natural ecology of many areas. Construction companies have come under criticism from environmentalists. Nowadays, the use of sand and gravel exceeds local supply, so these materials are imported not only far from the construction site within Korea, but also from other countries, mainly from China. Poor quality sand is imported at a cheap price, so there is another risk of failure of buildings because of the quality of the materials. Requirements for transport and associated infrastructure have become a major problem.

With the economic growth and construction boom, increases of salary for labourers has appeared as a new problem. The increase of labour costs exceeded ten percent per year between 1988 and 1993, while that of materials were around five percent per year over the same time. The increase of labour costs between 1990 and 1993 is more than twenty percent per year with a peak in 1991 of a 33 percent increase over the previous year. Therefore, average wages in 1994 were 358 percent of those in 1985.[7] The cost of labour now exceeds that for materials used, so construction companies have tried to find a new method for construction using machines rather than labourers, leading to energy-intense development.

For the assessment of building materials, a standard fifteen-storey apartment block which contains 89 number of 59 square metre units built by Korea National Housing Corporation (KNHC) has been chosen. The total areas of this block including public spaces such as corridors, a lift and staircase is about 7169 m^2. The costs shown in the table are based on the cost analysis published by KNHC in 1994.[8] Costs for machinery, electricity, communication, infra-structure and landscape are included in the category of **Others** in the Table 5-4. In accordance with the increased requirement of building services as the standard of living rises, the costs of machinery, electricity and communication have elevated more rapidly than those of the building fabric itself. The requirement of computer internet lines as well as telephone and fax lines has increased even in homes, and better equipment for heating and electric facilities should be installed at the resident's requirement.

Table 5-4. Construction Cost in an Apartment Building (15 storey - 89 units (59m^2))[9]

	Building	Others	Total
Material (Won/m^2)	96,437	45,043	141,480
Labour (Won/m^2)	113,674	49,581	163,255
Expense (Won/m^2)	18,154	6,186	24,312
Sundry Expenses (Won/m^2)	28,126	18,871	46,997
Total (Won/m^2)	256,391	119,653	376,044
Per Unit (Thousand Won)	20,652	9638	30,290
Per Block (Thousand Won)	1,838,049	857,784	2,695,833
Per Block (£)	1,470,439	686,227	2,156,666

Source : KNHC, *Housing Construction Cost Analysis*, KNHC 1994, p38

The price shown in Table 5-4 does not include the price of land and levelling the ground. Construction costs in big cities will increase since the price of the land is very high.[10] The cost of transportation for construction materials could also be different according to the site. Since the price list comes from the Korea National Housing Cooperation (KNHC) run by the Government, it is slightly cheaper than that of private companies. Private companies tend to use more luxury materials for decoration and finishing. Prices in the future can hardly be predicted because of the rapid change in costs especially for labour. The expected shortage of basic materials such as sand and gravel is another element for deciding the future construction cost.

The main materials used in this apartment block are listed in the Table 5-5. The order of the list is based on the list in Chapter 4. The price of six chosen materials assessed in the previous chapter occupies around forty-five percent of the total, making a substantial portion of the materials used.

Table 5-5. Materials used in an Apartment Building (59m^2-89 units)

Name		Unit	Quantity	Price (Thousand Won)	Price (%)
Concrete	Ready mixed Concrete	m^3	3,464.08	136,974	14.65
	Concrete pile	piece	354.00	23,350	2.50
Steel	Reinforcing Rod	tonne	404.25	101,486	10.85
	Cast iron	tonne	36.00	12,135	1.30
Brick	Cement Brick	piece	238,737.00	7,866	0.84
Timber	Hardwood	m^3	129.50	57,170	6.11
	Softwood	m^3	133.20	38,124	4.08
	Plywood	m^2	3,665.79	23,605	2.52
Insulation	Mineral wool	m^3	19.58	6,528	0.70
	Plastic insulation	m^3	215.02	6,373	0.68
	Glass wool	m^3	87.87	2,530	0.27
Glass	Flat Glass	m^2	1,337.24	3,110	0.33
Subtotal				**419,251**	**44.83**
Others	Sanitary wares	piece	89.00	30,011	3.20
	Copper pipe	M	25,195.21	25,145	2.69
	Lighting facility			21,833	2.33
	Panel	m^2	869.62	19,693	2.11
	Cement	tonne	303.12	17,776	1.90
	Tile	m^2	2,356.00	14,268	1.53
	Wall paper	m^2	16,916.90	7,156	0.77
	Plaster plate	m^2	5,166.00	6,462	0.69
	Sand	m^3	649.05	5,841	0.62
	Paint	L	2,791.99	4,847	0.52
	Electric wire	M	42,054.30	3,276	0.35
	Gravel	m^3	361.52	2,832	0.30
	Cable	M	1,764.30	594	0.06
	Others			356,290	38.09
Total - Building Only				935,275	100.00
Total - Including Landscape				1,014,260	

Source: KNHC, *Housing Construction Cost Analysis*, KNHC 1994, pp. 24-136.

The price for concrete and steel is almost 30 per cent of the total price because the main structure of the building is reinforced concrete. Most of the buildings are shaped with concrete, painted on the surfaces. Bricks are only used as a supplement of concrete in places not requiring structural strength. The brick used is, therefore, a cement brick.[11] The volume of cement is still big compared to the other materials, but it is only less than ten percent of the concrete volume. Reinforcing rods occupy around ten percent of the total materials' price. Besides this, more steel is used as joints, nails etc. categorised as cast iron in this table.

The price of timber also accounts for a large proportion, occupying around thirteen per cent of the total price including plywood. Since little timber for the construction is produced in Korea, most timbers are imported from abroad, mainly from south-east Asia. The price is, therefore, relatively high compared to the volume. Pine as a soft wood is the most used, while some hardwoods are used for scaffolding and other purposes. Steel scaffolding tends to replace wood scaffolding nowadays because it can be used many times.

Apart from the materials assessed in the previous chapter, some other materials are used in significant proportions. Quite a lot of copper pipes are used for underground heating systems in the apartment building, distinguishing Korean apartment buildings from those of other countries. Sanitary wares occupy the biggest price portion apart from the six assessed materials. These are mainly for equipment in the bathrooms. The materials for finishing internal parts are mainly wall-paper, ceiling paper and floor paper in the bedrooms. Floor areas of living rooms and kitchen-dining rooms tend to be covered by vinyl-as-tile or wood. Tile is used on the wall, ceiling and floor areas of bathrooms.

Reuse or Recycling of Used Materials

Waste problems for construction materials have become more serious recently. Although other wastes have been reduced as seen in Chapter 2, construction wastes have increased in the recent period. Recent trends of reconstruction of old apartment estates have a great effect on construction waste problems. One report indicated that 50 tonne of construction waste will be produced whilst reconstructing an apartment unit of 25 PY (82.5 m^2).[12] Among them, 40 tonnes is produced by old buildings and the remaining 10 tonnes is during constructing new buildings. This is an equivalent amount of one family's waste production of 20 years in Seoul. To reuse or recycling of them is, therefore, very important issue, not only for preserving building materials but also for solutions of waste problems.

There are some attempts in Korea to reuse building materials, but it is difficult to do. The main reason is the difficulty in separating waste. Even though steel is easy to recycle, difficulty of separation between steel and concrete makes reinforcing rods from waste concrete hard to use again. The case of copper piping used for underfloor heating is the same. Some small companies have been launched to recycle building materials through separating components of destroyed buildings in the 1990s. One of main tasks of the companies is to separate steel, reinforcing rod, copper pipes, etc., from concrete mass. They also try to break concrete into fragments in order to be used as aggregates for new buildings.

The use of recycled materials has another problem because of the quality of the reused materials. Since it is now popular to redevelop old housing estates in Korea, further research for reusing and recycling the waste materials are essential for both preserving raw materials and solving waste problems.

5-2-2. Embodied Energy of Building Materials

Within a relatively short period of time, embodied energy issues have become one of the issues for sustainable architecture in western countries. In the case of developing countries like Korea, however, energy consumption for building materials production is not a big issue. Bigger topics, such as the rate of buildings in a short time because of massive economic growth and population increase, safety of buildings, regional air pollution and health problems, exceed the claim for using less energy content materials. However, current global concerns for the environment will prevent the use of much energy for producing building materials, hence the subsequent product of CO_2, even in developing countries like Korea.

Table 5-6. Embodied Energy of Materials used in an Apartment Block (59 m^2, 89 apartment units)

Material		Quantity (Tonne)	Embodied energy (KWH/tonne)	Embodied energy (KWH)	Percentage of Total Embodied Energy (%)
Concrete	Ready mixed Concrete	7,828.82	226	1,769,313	15.71
	Concrete pile	538.81	226	121,771	1.08
Steel	Reinforcing Rod	344.23	6,100	2,099,803	18.64
	Section and Strip	36.00	4,650	167,400	1.49
Brick	Cement Brick	395.59	320	126,589	1.12
Timber	Hardwood	99.59	2,700	268,880	2.39
	Softwood	68.33	2,200	150,326	1.33
	Plywood	21.76	3,000	65,280	0.58
Insulation	Plastic insulation	4.30	32,000	137,600	1.22
	Mineral wool	2.35	8,300	19,501	0.17
	Glass wool	11.60	7,200	83,520	0.74
Glass	Glass	10.11	4,000	40,440	0.36
Sub Total				5,050,423	44.83
Total (Sub Total x 100/44.83)				11,265,721	100.00
Total per m^2 (Total / 7169)				1,571	-

For proper assessment, the process of production should be investigated for each company. It is not easy, however, because companies tend not to divulge the energy contents of materials for the image of them. The processes are too complicated to get a confident value for energy content of materials. The data shown in chapter 4 (Table 4-9) are used for assessing embodied energy of materials, which is mainly from research in the United Kingdom. Even though it could be inaccurate because of the different situations between Korea and the United Kingdom, this assessment, at least, can be a foundation for further research. The values for reinforcing rod and cast iron are taken as mean value of new and recycled figures since about half of them are made by recycled steel.

Materials are indicated by the weight (tonne) for the assessment. All materials shown by volume are converted to weight.[13] The apartment building used for this embodied energy figure is the same building used in the previous section; consisting of 89 housing units of a $59m^2$ size, and total floor area of 7169 m^2, built by KNHC (Korea National Housing Cooperation).

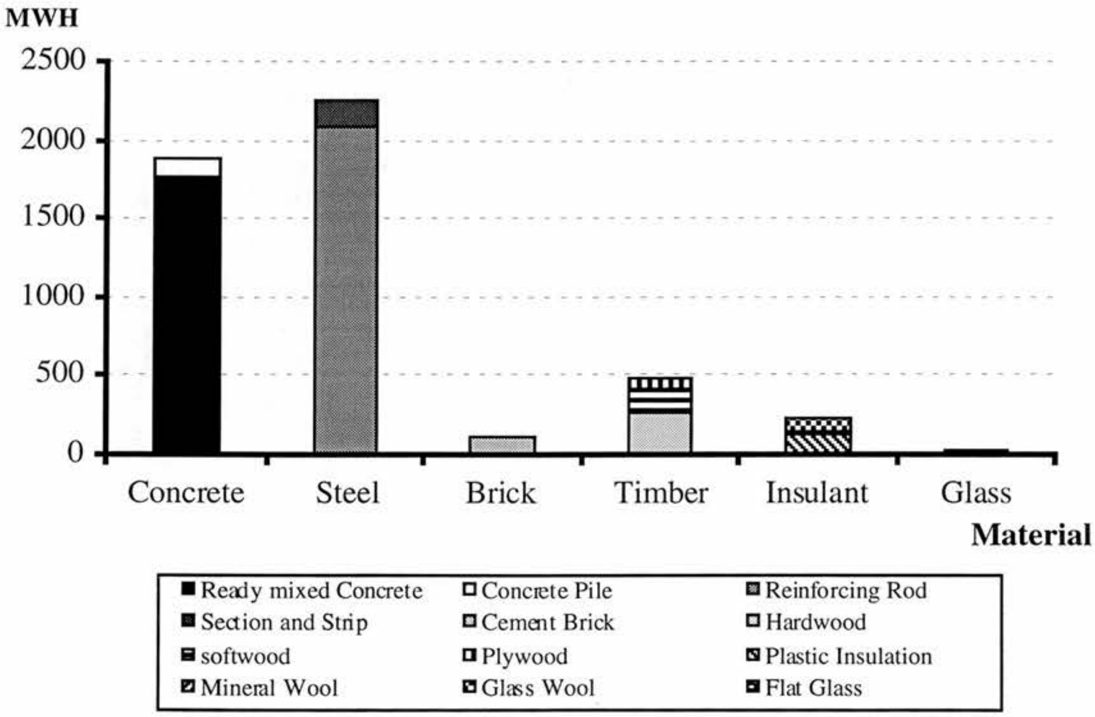


Figure 5-2. Embodied Energy of Materials in an Apartment Building

The price of calculated embodied energy in the above table is about 45 percent of the total materials used according to the price of the materials, so we may assume that the total energy for this block will be around 11,265 MWH. However, it is difficult to assume the rest, because the values of embodied energy are quite different from those of the materials' price. There is a big discrepancy between the price and the embodied energy of each material. A comparison of embodied energy of six materials for this apartment building is shown in Figure 5-2.

In the same way, CO_2 production for each material is calculated and shown in Table 5-7 and Figure 5-3. Values for reinforcing rod and cast iron are again a mean value of new and recycled.

Table 5-7. CO_2 Production of Materials used in an Apartment block (59 m^2 - 89 units)

Material		Quantity (Tonne)	CO_2 Production (kg/tonne)	CO_2 Production (kg)	Percentage of Total CO_2 Production (%)
Concrete	Ready mixed Concrete	7,828.82	135	1,056,891	18.52
	Concrete pile	538.81	135	72,739	1.27
Steel	Reinforcing Rod	344.23	2,450	1,067,113	18.70
	Section and Strip	36.00	2,150	93,600	1.64
Brick	Cement Brick	395.59	200	79,118	1.39
Timber	Hardwood	99.59	2,000	199,118	3.49
	Softwood	68.33	16,00	109,328	1.92
	Plywood	21.76	16,00	34,816	0.61
Insulation	Plastic insulation	4.30	9,700	41,710	0.73
	Mineral wool	2.35	2,500	5,875	0.12
	Glass wool	11.60	2,300	26,680	0.47
Glass	Glass	10.11	1,100	11,121	0.19
Sub Total				2,558,160	44.83
Total (Sub Total x 100/44.83)				5,706,357	100.00
Total per m^2 (Total / 7169)				796	

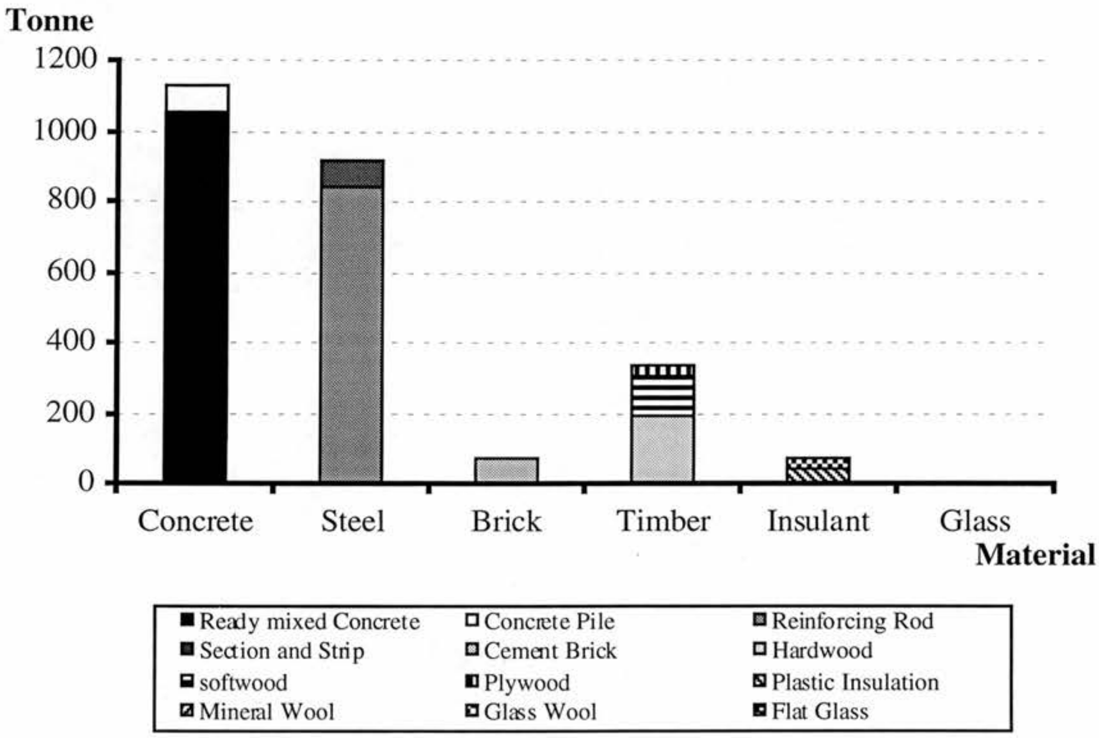


Figure 5-3. CO_2 Production of Materials in an Apartment Building

From these, values of embodied energy and CO_2 production for the whole Pundang new town can be estimated. Even though the size of apartment buildings varies, it is possible to multiply the value by the number of building, because this example building has almost the mean value for them all. Details are in Chapter 3. The number of apartment buildings in Pundang is 1335.

Table 5-8. Embodied Energy and CO_2 Production for constructing an Apartment Building and Apartment Construction in the Entire Pundang New Town

	Embodied Energy (MWH)	CO_2 Production (tonne)
An Apartment Building	11,266	5,706
All Apartment Buildings in Pundang	1,504,110	7,617,510

5-2-3. Assessment of Building Materials

The thorough investigation of the assessment of building materials through this section took from the case of KHNC, one of public construction companies in Korea. The materials used by private companies tend to be slightly more luxurious, which may require more cost both in money and energy, but just a minor differences because all buildings have almost the same structure. Summary of credit points and grade of EIAHA step 3 and step 4 of 5 estates are shown in Table 5-9.

Table 5-9. Summary of Credit Points for Building Materials

Item	(Maximum Points)	Credit				
	Apartment Estate	A	B	C	D	E
Step 3. Building Materials - Ecological and Health						
Insulation	(3)	3	2	2	3	3
Wood	(3)	2	2	2	1	2
Health	(2)	2	2	1	1	1
Recycling	(2)	1	1	1	1	1
Total Points	(10)	8	7	7	6	7
Grade		Good	Medium	Medium	Medium	Medium
Step 4. Materials' Embodied Energy						
Concern	(4)	2	2	0	0	2
Value	(6)	3	2	2	3	3
Total Points	(10)	5	4	2	3	5
Grade		Medium	Bad	Bad	Bad	Medium

The issue of building materials in terms of environment has not well been recognised in Korea. However, the recognition of global environmental disorder such as ozone depletion and loss of tropical forests leads to think of wise use of building materials. The efforts for using re-cycled materials have also been increased, but use of them is not still sufficient. The importance of the embodied energy of building material is not widely known, which results a requirement of siginificant improvement in this area.

5-3. Energy Use during Building Occupancy for Thermal Performance

5-3-1. Energy Use for Thermal Comfort in Korean Apartment Buildings

Buildings in Korea require heating in winter and cooling in summer, because Korea has a hot humid summer and a cold freezing winter. In residential buildings, cooling facilities have not been widely used, even though the number of households with air-conditioning is now increasing. The increased installation of air-conditioning is not only because of economic ability but also due to the increase of air temperature year by year, as shown in Chapter 2. It is still an option to have air conditioning against hot weather conditions, but it is hard to live without any heating system in winter, because the temperature in winter is below zero for quite a number of days.

Even with the effort to have good design for passive heating and insulation, apartment buildings in Korea cannot avoid the need for mechanical heating facilities in order to have comfortable thermal conditions. Heating costs of apartment buildings change dramatically according to the seasons. As a reference of energy use in a Korean apartment, energy bills of Hanyang apartment estate in Pundang New Town between October 1993 and October 1994 are assessed and shown in Figure 5-4.[14] This estate has 28 tower blocks which contain 2409 household units of various sizes from 40 square metre to 260 square metres.[15] Total floor areas for this estate is 353,205 m^2. Big changes for heating bills start in October. Hot water bills are rather stable, with slight increases in winter. The notable difference in the electric bill in August 1994 is due to the use of electric fan and air conditioning. The electric bill starts to increase from June and suddenly drop down in September which is the best month in terms of temperature.

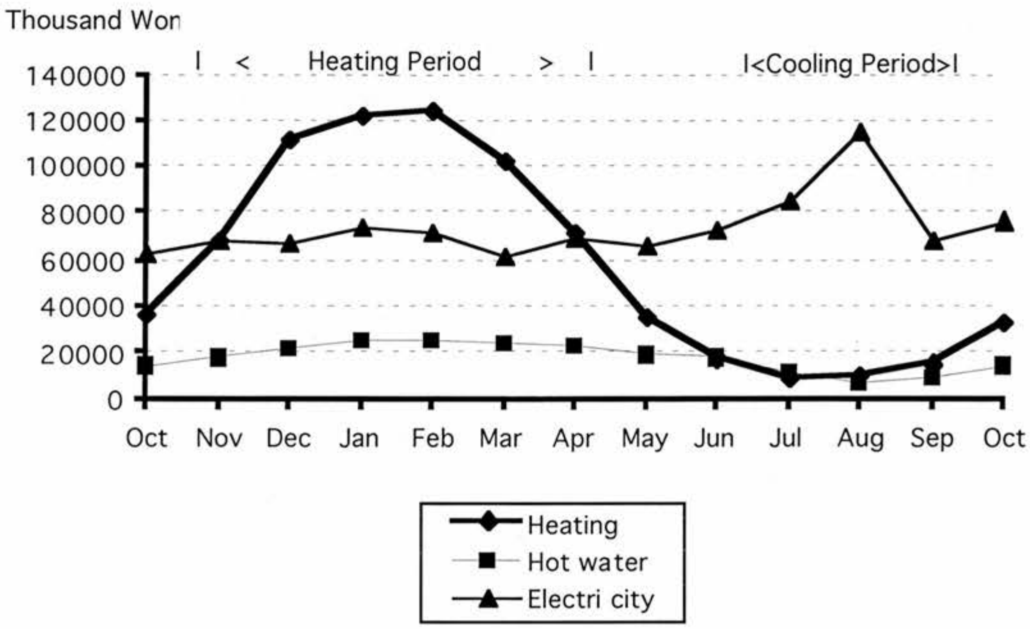


Figure 5-4. Heating, Hot water and electricity bill by the Month between October 1993 and October 1994
- In the case of Han Yang apartment estate in Pundang

Source : Monthly Management Fee Statement of Han Yang Apartment Estate (October 1993 - October 1994)

Through converting this figure to energy consumption, it is found that the energy of 46,193 MWH is used in this estate for a calendar year. The figure indicates that about 130 KWH of energy is used per square metre in this period. (October 1993 - September 1994) The value includes the use of energy for outer buildings such as lighting for tennis court and street lamps.

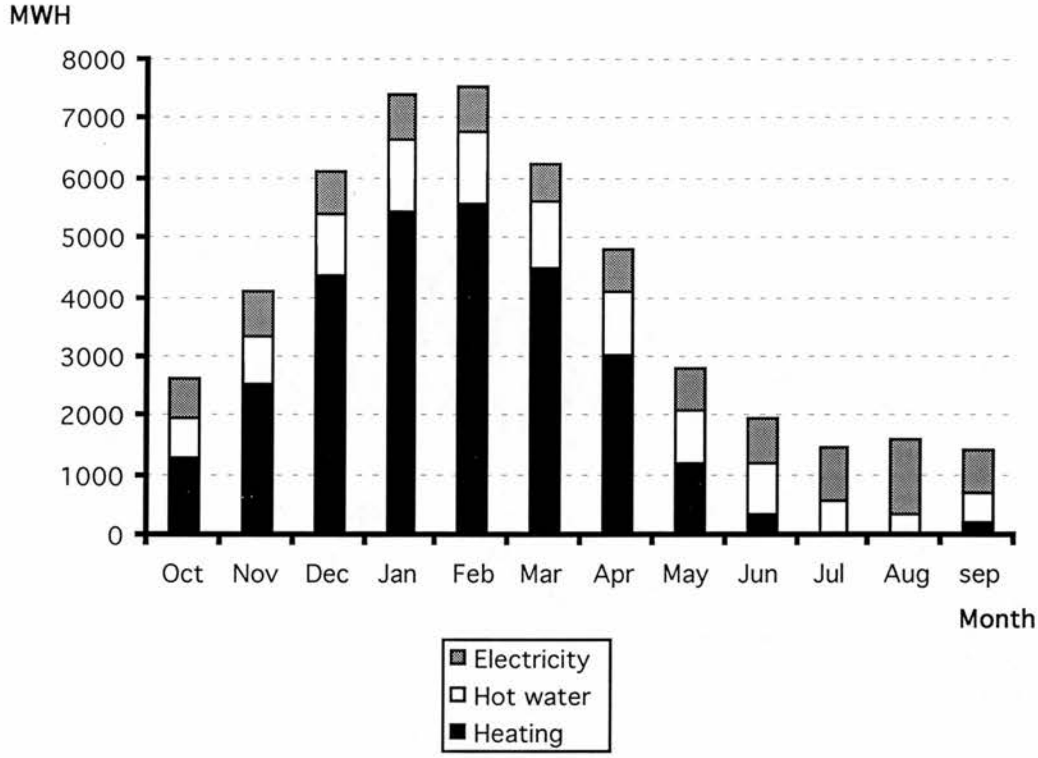


Figure 5-5. Energy Used for Heating, Hot water and Electricity by the Month between October 1993 and September 1994 in Han Yang Estate

Another example of seasonal differences for using energy for space heating and hot water is in Figure 5-6.[16] This is the figure of an apartment estate in Seoul which has 56 apartment buildings with 4494 household units. This estate used to have a central heating system, and changed the system to a district heating system in the middle of 1992. This figure is based on the central heating system. The seasonal differences for heating energy are easily found, while hot water energy is relatively stable. The use of heat for heating in August was almost negligible. Heating is sometimes required simply for dehumidification in July, even with hot temperatures.

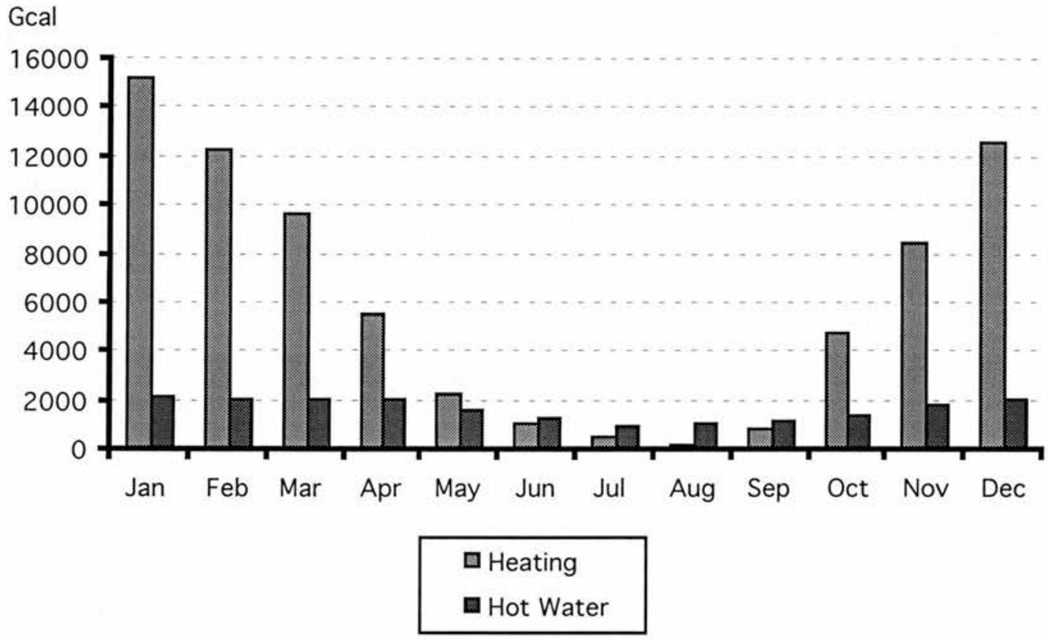


Figure 5-6. Energy for Heating and Hot water according to the months in 1991 - in the case of an apartment estate in Seoul

Source : Namho Lee et.al, *A Study on the Improvement of Apartment Heating Installations Coupled with District Heating Systems,* Korea Institute of Energy Research, 1993

5-3-2. Central Heating and District Heating

Types of heating systems in Korean apartment buildings are divided into individual heating, central heating and district heating systems. Individual heating systems are usually used in small estates with a few low-rise apartment buildings. Most high-rise apartments have a central heating or a district heating system.

Most apartment buildings that have central heating systems adopt an intermittent heating mode in order to save energy consumption. This mode supplies heat three to five times a day for a few hours according to the season. Although the system can save energy compared to the individual system, it has some disadvantages such as temporary overheating, inefficiency of equipment operation, excessive investment in heating equipment, increase of loads due to preheating and thermal mass storage, and large indoor temperature fluctuations.[17] A concrete mass under the floor area of each room can store the heat while heating is provided, and release it during non-heating hours. For equal thermal conditions between high and low zones of each apartment block, the multi-zone heating system is required in building regulations. If a block does not have a multi-zone heating system, apartment units in high storeys are overheated while those in low storeys do not have enough heat. For a fifteen storey apartment, three zones are required to provide each unit with equal thermal conditions.

As an extension of a central heating system to a town level, District Heating Systems (DHS) are applied to large new apartment building sites as well as to office and commercial building complexes. The district heating method is a quite new method in Korea. The Korea District Heating Corporation (KDHC) was established in 1985 for energy efficiency and better living conditions. District heating systems started to operate in 1987 in Korea, although a feasibility study for a power plant near Seoul was carried out for basic knowledge of district heating systems in 1973. Since district heating was supplied to about 40,000 households in apartment buildings and 119 office buildings in Yoido, Banpo and Dongbuichon districts in Seoul by November 1987 by the KDHC, the number increased to about 340,000 households and 700 office or commercial buildings in five new towns around Seoul and Kangnam district in Seoul by the end of 1994.[18] The number of apartment units supplied by district heating will be 537,000 by 1997.

District heating systems (DHS) consume less fuel and emit fewer pollutants, such as SOx, NOx, CO_2, dust, etc. than Individual Heating Systems and Central Heating Systems. Pollutant emissions from DHSs are nearly half that of Central Heating Systems, with just one third in the case of SOx emissions.[19] In addition to the reduction of pollutants, a district heating system creates an easier and more comfortable environment. The system makes it possible for customers to use space heating and hot water around the clock, which was not possible for the intermittent heating method of central heating system. Adopting the individual meters it became more reasonable in cutting down the heat cost and keeping proper indoor temperatures.

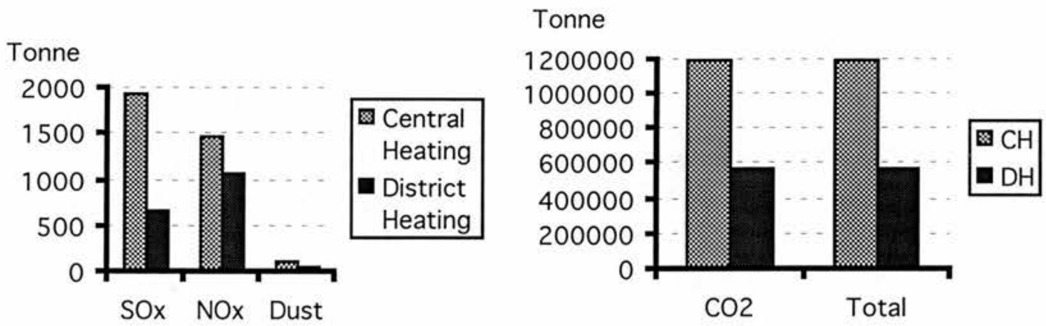


Figure 5-7. Comparison of Air Pollutants between Central and District Heating Mode.

Source : KDHC, *District Heating*, Korea District Heating Corporation, p9

From the results of research by the Korea Institute of Energy Research (KIER), an apartment group that changed heating system from central heating to district heating reduced its energy consumption by about 30 percent in winter. Figure 5-8 presents the statistics from an apartment estate in Seoul, with 56 apartment blocks and 4,494 households, that changed the heating system from central heating to district heating in May 1992.[20]

Each item taken in Figure 5-8 is the value of January in each year. The figure in 1991 and 1992 is based on central heating system and that of 1993 is based on district heating system. Each year has different weather conditions. The simplest comparison will be outdoor temperature. The outdoor mean temperature in January each year was -3.2 in 1991, -1.1 in 1992 and -2.2 in 1993. Even with colder weather in 1993 compare to that in 1992, less energy was consumed because of a different heating system.

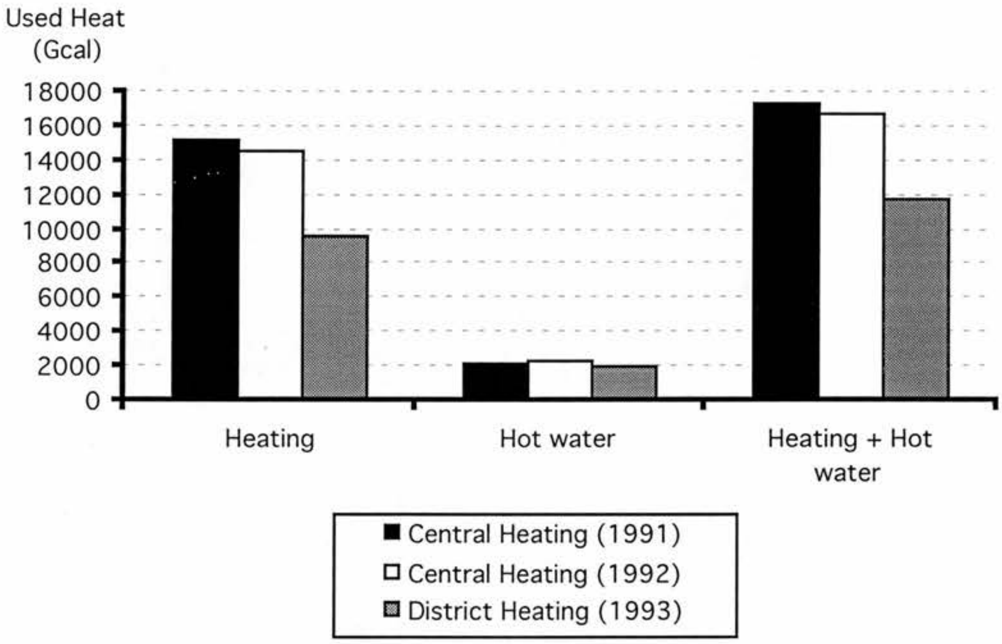


Figure 5-8. Comparision of Energy use for Heating and Hot water between Central Heating and District Heating System
- the same apartment estate of that in Figure 5-6

Source : Korea Institute of Energy Research, *A Study on the Improvement of Apartment Building Heating Installations Coupled with District Heating Systems,* 1993

Among the apartment buildings using a district heating system, those in Seoul did not originally have the system. These buildings have changed their heating systems from central to district. Individual buildings, which have a district heating system, only need space for a heat exchanger, hot water tank and circulation pump. Since facilities for central heating need more space for operation, the saved spaces are converted to convenient facilities for the residents such as study rooms, health centres or laundries.[21]

In the process of operating a District Heating System, Combined Heat and Power (CHP) Plant is applied. CHP produces heat and electric power simultaneously, so it can contribute to rapidly increasing demand resulting from economic growth with the merit of a high degree of energy efficiency.

Even with these advantages, District Heating Systems should be dealt with carefully. Proper management of long pipelines for providing heat resources should be carried out to avoid possible accidents. Through adopting appropriate hot water temperature, energy efficiency in running the system can and must be achieved, while providing pleasant indoor thermal conditions.

5-3-3. Underfloor Heating (Ondol)

Korea has developed its own heating system using underfloor heating equipment named *Ondol*. The *Ondol* was derived from *Whaduk*, the heating instrument of primitive Koreans. *Whaduk* consisted of a rock bed playing the role of a heat storage media, and it was located on the central part of the floor in the house. *Whaduk* had been used for a long period, from the Neolithic era to the end of the Bronze Age.[22] Since the beginning of the Iron Age, *Ondol* has been developed naturally by the populace. At the first stage of the development of the system, *Ondol* consisted of a furnace, heated air passages and chimney. The heat source of burning wood passes heat through an underfloor hole to chimneys to make rooms warm. This type continued to be used until the 1950s, when the fuel was changed from fire-wood to anthracite coal. At the current stage, since the 1960s, hot water floor heating systems with embedded tubes have been used.[23] This dramatic change, using heating water rather than burnt gas, was due to accidents such as death from suffocation, when CO gas permeates through floor leaks where anthracite coal is burnt. Boiler systems using anthracite coal, which was dominant for hot water underfloor heating, were replaced by oil boilers, since the late 1970s, and then to gas boiler systems since the mid-1980s.[24]

An underfloor heating system can give people more comfortable conditions even in lower air temperatures, but it needs careful design for construction since the pipe for carrying heat is installed in the main structure. Korean people, who have used underfloor heating modes for a long period, tend to have different thermal comfort ranges. Although comfortable air temperature ranges of Korean people are similar to standards of other countries, ranging from 20.5 - 22.5°C, comfortable temperature on the floor is much higher than for others. Korean people even feel comfortable in much lower air temperature, if the floor is warm enough.[25]

Most Korean apartments, whether high-rise or low-rise, use underfloor heating mode using hot water pipes. The heating pipe is installed above a concrete slab, within gravel or mortar. Regulations on structure and materials of underground heating systems are described in the Architecture Law (Building Regulation), providing the least heat loss and safety for the structure. These regulations are shown in Table 5-10.

Table 5-10. Regulation on Structure and Material of Underground Heating

Element	Structure and Materials
Base	Depth : 30 mm or more Material : Concrete Waterproof if adjacent to the earth
Insulation	Insulation materials are defined by regulation number 21
Heat Storage	Depth : 40-70 mm or less Material : aggregate, mortar, concrete
Radiate Pipe	Material: erosion-free and heat-resistent Diameter : 15 mm or more Distance : 150 - 300 or less
Length of pipe in a unit	50 m or less

Source : *Architecture Law* (Building Regulation)

Within the regulation, construction companies have developed their own method to install the system.

Connected with the district heating system, the underfloor heating mode has been improved in terms of energy efficiency for residential buildings. There has been research concerning appropriateness of tube diameter which will fit the district heating mode. However, careful selection of materials for tubing, not only by thermal performance but also for the embodied energy of them, should be considered. Since it is difficult to change the tube, materials lasting the life-time of the building should be selected, although they require higher initial costs.

5-3-4. Assessment of Heating System

The assessment of Step 5 of EIAHA for the five estates is the same since all of them are supplied heat and hot water through one district heating system power station. This power station save about 30 % of energy and reduce the same proportion of CO_2 emissions, compare to a central heating system. There are just a few differences in the assessment of Step 6 of EIAHA according to estates, since the distribution system of heat supply is shared by all the estates in Pundang new town. The big difference here is complaints of heating bill in an apartment estate, where there has been a failure of the metering system. Summary of credit points and grade for heating system is shown in Table 5-11.

Table 5-11. Summary of Credit Points for Heating System

Item	(Maximum Points)	Credit				
	Apartment Estate	A	B	C	D	E
Step 5. Heating Mode						
Heating Mode	(5)	5	5	5	5	5
Fuel Type	(5)	3	3	3	3	3
Total Points	(10)	8	8	8	8	8
Grade		Good	Good	Good	Good	Good
Step 6. Operation of Heating System						
Control	(2)	2	2	2	2	2
Metering	(2)	2	2	2	2	2
Complaints	(2)	2	1	1	0	2
Equality	(2)	1	2	1	1	1
Comfort	(2)	2	2	2	2	2
Total Points	(10)	9	9	8	7	9
Grade		Good	Good	Good	Medium	Good

Generally, the heating system is well equipped in current high-rise estate development, since an advanced district heating system with combined heat and power has been installed in recent new town developments. Existing estates also tend to change the heating system from central heating mode to district heating mode, which can save annual energy by 30 percent. The only problem here is the cooperation between district heating company and residents in order to avoiding complaints about control and metering of the system. Use of garbage for energy source is also incouraged, as well as low-pollution gas insted of oil which is now occupied more than 70 percent of fuel used.

5-4. Apartment Management and Maintenance

5-4-1. The Apartment Management System

An apartment is a different type of dwelling from a house since it has public facilities which every unit shares in addition to its own private space. The management of an apartment estate needs to mediate between the different view points of each resident and to maintain public facilities. Apartment residents are required to establish a management office[26] to manage and maintain public facilities and to decide management criteria. The residents share the expenses of management and maintenance. A management office is usually staffed by a chief manager, officers, technicians, electricians, and security guards.[27]

Standards of apartment management have existed since 1979 in a part of Architecture Law (building regulation). Under the Law, apartment estates are divided into three groups; (1) an estate that has less than 20 housing units, (2) an estate that has between 20 and 299 housing units without lift and central heating facilities, and (3) an estate that has more than 300 housing units or which has lift or central heating facilities. Only a few standards for management and maintenance are applied for the first two groups, but all standards must meet the requirements for the last group. Every high-rise apartment that is six storeys high or more is required to have lift facilities and this means that every high-rise apartment over six storeys falls into group (3). All apartment estates in Pundang new town are in this group and are required to meet the most exacting of standards.

The regulations for apartment management started in 1963 with the introduction of the Regulation for Public Housing. This regulation was included in the law named the Housing Construction Promotion Regulation at the end of 1972. The housing manager system was established in 1977. Standards for housing maintenance and long-term repair plans were introduced in 1983, and several rules have been changed or created in the 1980s and 1990s. Previously the standards were just a system for management, but this has changed to become long-term plans for preventing deterioration, preserving living environment, maintaining property value, etc. In 1989, an expert manager[28] was recommended and mandates from 1994 for third category apartment groups. [29]

When an apartment estate is built, the construction company is required to manage it for one year to give the residents an opportunity to arrange their own management system. After that compulsory period, the residents have to decide between one of two types of management system: the self-management system or the trust-management system. In both systems, there are two components: a management organisation that manages and maintains the apartment estate, and a committee organised by residents as a legislative organ. A management organisation has a chief manager with some officers, technicians, guards, and cleaners according to the size of each estate, and the managers have their own office space inside the apartment estate. The only difference between the self-management system and trust-management system is the method of selecting managers. The committee elects each manager for the self-management system but the committee only decides the management company, which will decide the managers, for the trust-management system. Big apartment blocks like those in new towns tend to have the trust-management system, even though more than half of all apartment blocks have the self-management system around the country.

The job of each management office is divided into management and maintenance. Apartment managers[30] provide services according to the apartment management regulation and under the control of residents' committee. They also deal with collecting management fees and public charges[31], planning finances, and making budget and balancing accounts. In addition, they maintain and repair public facilities within their estate. They also deal with cleaning, disinfection, waste removal and safety supervision.[32] For the apartment estates of the third group of the previous page, they have to make long-term repair plans and collect the funds for the plans.

The management offices produce statements of expense items each month. The items include general management expenses[33], cleaning fees, disinfecting fees, lift maintenance, heating, hot water, repair-maintenance fees, appropriation funds for special repair, water and electricity fee. Table 12 shows the monthly management fee of an apartment estate in Pundang in January, April, July and October of 1994. The total household number of this table is 2419.

The general management fee, cleaning fee, disinfection fee, lift maintenance fee, repair fee and fund for special repair are assessed according to the size of each unit. Total amounts for these are slightly increased month by month because of inflation, and were around 140 million won (or £ 112 thousand) in October 1994. Each apartment unit shares the amount according to the size of the unit.[34] The expenses for better maintenance are those for lift maintenance, repair-maintenance and funds for special repair, and these are around one tenth of the general management. To ensure adequate maintenance, funds for special repair needs to be increased in order to have a proper long-term repair plan. In Japan, for example, the maintenance fee is usually almost the same as the management fee for the longer life expectancy buildings.[35] Heating and hot & cool water fees are assessed according to each unit's used amount, with the standard fee for heating and hot water. The electricity fee is divided into that for public use such as street lights, lights for tennis courts, electricity for the lift facilities, etc., and private use, which is used by the unit itself. The electricity fee for public use is divided in between each unit according to the unit size, and that for private use is assessed like the heating and water fee. Heating and hot water fees vary according to the season. The electricity fee in summer is higher than the other seasons because of the use of mechanical cooling systems and electric fans.

Table 5-12. Monthly Management Fee in Hanyang Estate in Pundang

(Unit : Korean won)

	January	April	July	October
General management	98,252,959	99,920,259	105,448,653	107,539,024
Cleaning	14,272,010	14,272,020	14,272,000	14,272,010
Disinfection	4,183,550	4,197,650	4,197,650	4,197,650
Subtotal	116,708,610	118,389,929	123,918,303	126,008,648
Heating	122,347,338	72,496,860	9,693,370	33,248,260
Hot Water	24,158,400	22,069,220	11,545,200	14,426,400
Water	10,312,170	7,402,220	11,966,435	13,977,630
Electricity	74,393,450	69,956,160	84,715,920	77,486,480
Subtotal	231,211,358	171,924,460	117,920,925	139,138,770
Lift maintenance	3,459,500	3,459,500	3,459,500	3,459,500
Repair-Maintenance	2,112,441	5,740,991	6,234,858	7,641,650
Fund for special repair	-	2,807,282	2,807,000	2,807,000
Subtotal	5,571,941	12,007,773	12,501,358	13,908,150
Others[36]	-	-	-	1,512,030
Total	355,491,818	302,322,132	254,340,596	280,567,634

source : Items of management fee from November 1993 to October 1994 published by Han-Yang apartment management office in Pundang new town.

The repair-maintenance fee is money used for maintaining the building and funds for short-term repair such as money for water tank cleaning, while the fund for special repair is for the long-term repair plan.

5-4-2. Long-term Repair Plan and the Fund for Special Repair

An apartment building reduces its function according to the period of the building's life, and finally reaches to the point of demolition. The reason for demolition varies according to its physical, social or functional, and economical life.[37] The physical life is entirely one of deterioration because of abrasion, damage, erosion, fire, etc. Usually, the physical life for reinforced concrete buildings is the time of erosion of the reinforced rod in the main structure, around 60 years. Provided the structure is basically sound it is possible with proper maintenance to extend the physical life of a building almost indefinitely. In the course of time it will tend to become increasingly unsuitable for the functional purpose for which it was originally designed.[38] Some buildings including apartment blocks are, therefore, destroyed earlier than the limit of their physical life. Its functional and social life exists because of the modernisation of life styles since most people are eager to improve their standard of living. Therefore, if the building does not adopt to change, it becomes obsolete long before its life expectancy. For extending these years of durability, designers have to estimate the future requirements of facilities. Its economic life depends on the expenses of maintenance and repair, which can exceed the expense of reconstruction.

Deteriorated apartments have been run-down and reconstructed since the 1980s in order to produce better living environment. A deteriorated apartment that can be reconstructed has been defined by the regulations as follows:

1. A building that could collapse or seems to be dangerous and may cause injury.
2. A building which lasts more than 20 years, so the maintenance or management expenses are relatively high compared to the price of the building itself.
3. A building which lasts more than 20 years and is in poor condition compared to surrounding values[39], so benefits will be gained when it is reconstructed.

4. The building which is built in an unsafe area such as a flood plain or a sharply sloping area.
5. The building that has urgent reconstruction requirements because it looks bad, or because of coefficient of land utilisation, heating methods, structural defect and defective construction. [40]

The first three standards were introduced in 1987 and the remaining two standards in 1993. Recently, apartment buildings tend to be reconstructed when they are 20 or 25 years old, while a few apartment estates are reconstructed only in less than 10 years. A committee for reconstruction is required to be established when an apartment group is planned to be rebuilt. It usually takes around one year from making a committee to getting permission to reconstruct, and two more years are required until the completion of the new apartments. Bigger and higher estates take longer time than smaller and lower estates, making the duration up to three years. Since the price of land is very high in big cities, low-rise apartment estates are converted to high-rise apartment estates. In the reconstruction process, construction companies usually produce double the existing household unit number. Residents can have new, modern facilities without any extra expenses, because the construction company can make a profit by selling excess units. Modern facilities from reconstructed apartments require less maintenance expense, so the residents tend to agree to them even though they need to move to another place during the construction period. However, an apartment that was built after the 1980s is not easy to reconstruct, because most of the new apartments are high-rise. Construction companies will not be able to make profit on the reconstruction itself, so residents may need to pay the expenses. Demolition expenses are also high for high-rise apartments.

Therefore, high-rise apartments are required to last longer than they presently do. Long-term repair plans and the fund for repair plans are necessary. For helping managers and residents to keep good maintenance, the Ministry of Construction (MOC) and Korea National Housing Cooperation (KNHC) have produced recommendations for the repair programmes. Table 5-13 shows some of these recommendations.

Table 5-13. Recommended Duration for Repair Plan of the Ministry of Construction (MOC) and Korea National Housing Cooperation (KNHC)

(Unit : Year)

Part		Method	Time for Repair	
			MOC	KNHC
Roof	Waterproof	Repaste	25 (All) 8 (Part)	18 (All) 8 (Part)
	Roof drain & Gutter (PVC)	Repair	28 (All) 6 (Part)	25 (All) 5 (Part)
	Rooftop Handrail	Repainting Repair	5 (All) 25 (All)	7 (All) 25 (All)
Wall	Mortar	Repainting Repair	5 (All) 25 (All) 8 (Part)	7 (All) 25 (All) 7 (Part)
Main Door	Steel	Repainting	5 (All)	7 (All)
	Aluminium	Repair	40 (All) 20 (Part)	25 (All) 15 (Part)
Step & Corridor	Wall & ceiling Mortar	Repainting	5 (All)	7 (All)
	Non-slip	Repair	15 (All)	15 (All)
	Handrail	Repainting Repair	5 (All) 25 (All)	7 (All) 25(All)
Electricity	Power generation	Change	20 (All)	20 (All)
	Transformer	Change	20 (All)	20 (All)
Fire Equipment	Fire extinguisher	Change	20 (All)	
	Spring cooler	Change	25 (All)	
Lift	wire rope	Change	5 (All)	8 (All)
	Mechanical facility	Change	20 (All)	
Water supply pipe	steel	Change	15 (All)	15 (All)
Sewage pipe	steel	Change	15 (All)	15 (All)
	PVC	Change	25 (All)	25 (All)
	cast iron	Change	30 (All)	30 (All)
Gas pipe		Change	15 (All)	
Heating, Hot water	Boiler	Repair	15 (All) 10 (Part)	15 (All) 5 (Part)
	Circular Pump	Repair	10 (All) 5 (Part)	15 (All) 5 (Part)
	Hot water tank	Repair	15 (All)	20 (All)
Road	Asphalt	Repavement	12 (All)	20 (All) 5 (Part)
	Pedestrian Road	Repavement	12 (All) 7 (Part)	20 (All) 6 (Part)

Funds for special repair collected nowadays are usually much less than the money for the proper long-term repair plan. Residents are concerned with the amount of money rather than the condition and repair plan of their home. They seem to be accustomed to present reconstruction systems by which construction companies provide new housing units without requiring any money from them. Another reason is that residents tend to move house every 5 years. Therefore, funds for special repair meet only the minimum amount required by architecture regulation. The recommended amount is between 3/100 and 20/100 of the sum of the lift maintenance fee, heating and hot water fee, and repair-maintenance fee. Most apartment groups collect the money at 3/100 of the sum.[41] For the longer life apartment, a proper long term repair plan is required as well as education for resident's understanding and co-operation.

5-4-3. Life-cycle Energy Assessment of High-rise Apartments

Energy used for an apartment started from construction, by using building materials which contain energy during producing, transporting and assembling. During building operation, further energy is required for operation such as heating, hot water and electricity. There is also an energy requirement for maintenance and repair, whether they are regular or not. Initial energy requirement is usually big for high-rise buildings, which usually need energy-intense materials and construction method.

Embodied energy of building materials for initial construction for a high-rise apartment in Korea, which has 89 units of 59 m^2 size, is around 11,266 KWH, or 1,571 KWH/m^2. Through the figures of Han Yang estates in Pundang, energy used for heating, hot water and electricity is calculated to be 130 KWH/m^2/year. If the life of a building is 25 years, the value will be 3250 KWH/m^2/ 25 years. Initial embodied energy is more than energy used for 12 years operation. In other word, initial embodied energy is almost half of energy operation for the life of 25 years. If the building can last 50 years, double its life, the amount of energy for more than 12 years operation will be reduced. Although there will be an increase of energy consumption for repair and maintenance through the life, that for 50 years is usually between half and two thirds of initial embodied energy. If the usual repair and maintenance are applied, embodied energy for repair and maintenance will be a quarter of initial embodied energy for 25 years and three fifth of that for 50 years. Energy used for the life of 25 years and 50 years is shown in Table 5-14.

Table 5-14. Energy Use of Apartment Buildings for the Life of 25 Years and 50 Years

Unit : KWH/m^2

	25 Years	50 Years
Initial Embodied Energy	1,571	1,571
R&M Embodied Energy	393	944
Energy In-use	3,250	6,500
Total	5,214	9,015
Total/Year	209	180

The figure indicates that if the life of a building can be doubled, energy can be saved around 29 KWH per square metre per year. It means that energy consumption will be reduced by 193,563 KWH per apartment building per year, and 258,407 MWH per year for apartments in Pundang new town. This is equivalent energy for constructing 23 apartment buildings per year. If energy used for destruction is included, energy saving will even be increased.

5-4-4. Assessment of Building Life

Step 7 of EIAHA for Korean high-rise apartment buildings is difficult, because most of them are still less than 30 years old. This assessment, therefore, is merely guess work. According to current redevelopment of low- or medium-rise apartment buildings, where only 20 year-old buildings are destroyed for redeveloping the existing estates converting into more dense estates, the life of high-rise apartment buildings can be assumed around 30 years. One of the problems of the short life may be that there is no responsibility for construction company after 20 years of the construction, and management of the estate is hand over to management offices in one year. The assessment of Step 8 of the EIAHA represents that there is a room for improving the condition of building, by taking more careful consideration of maintenance programmes. This consideration may also help the building's longer-life expectancy.

Table 5-15. Summary of Credit Points for Building Life

Item	(Maximum Points)	Credit				
	Apartment Estate	A	B	C	D	E
Step 7. Building Life						
Life Expectation	(4)	1	1	1	1	1
Easy Repair	(3)	2	2	0	0	0
Social Aspect	(3)	1	1	1	1	1
Total Points	(10)	4	4	2	2	2
Grade		Bad	Bad	Bad	Bad	Bad
Step 8. Management and Maintenance						
Establishment	(2)	2	2	2	2	2
Fund	(4)	2	2	2	2	2
Long-term Repair	(2)	1	1	2	2	1
Short-term Repair	(2)	1	2	1	2	2
Total Points	(10)	6	7	7	8	7
Grade		Medium	Medium	Medium	Good	Medium

The life of apartment buildings has been extremely short, but recent efforts for extending the life of the buildings by establishing management offices with proper long-term repair plan will change the current trend. However, as shown in Step 7, there is still not enough consideration for building life in terms of easy-repair plan or social recognition of the importance of the life. Co-operation among residents, construction companies, management companies and the government is strongly required for improving the life, which helps to reduce the environmental impact and finances in the long term.

5-5. Appraisal of Current Korean Apartment Development

Through the application of each step of EIAHA in earlier parts, the character of Korean high-rise apartment developments in each step has been searched. Here, the holistic view of the character is described through the summary of the application of EIAHA into current Korean high-rise apartment. As mentioned before, each step has 10 credit points; if the credits obtained are 8 points or more, it will categorised to Good; between 5 and 7.9, Medium; and less than 4.9, Bad.

Table 5-16. Summary of Credit Points and Grade of Current Korean High-Rise Apartment Development by EIAHA

Step \ Apartment Estate	A	B	C	D	E	average	Grade
Step 1 Passive Solar Design	7	8	7	7	8	7.4	Medium
Step 2 Insulation and Ventilation	7	7	7	7	7	7.0	Medium
Step 3 Ecology and Health of Materials	8	7	7	6	7	7.0	Medium
Step 4 Materials' Embodied Energy	5	4	2	3	5	3.8	Bad
Step 5 Heating Mode	8	8	8	8	8	8.0	Good
Step 6 Operation of Heating System	9	9	8	7	9	8.4	Good
Step 7 Building Life	4	4	2	2	2	2.8	Bad
Step 8 Management System	6	7	7	8	7	7.0	Medium
Total	54	54	48	48	53	51.4	Medium

From the result of the assessment, the current Korean high-rise apartment development is medium in terms of the sustainability of global environment.

Mechanical heating system shown in Step 5 and Step 6 is well established, even though it needs continious improvements. However, there is a big discrepancy between steps. In terms of materials' embodied energy and building life, it is far below standard, which make apartment buildings less environmentally friendly. Although the total credit points is shown in the table, it does not have the absolute meaning. The important thing here is to look at the balance of each steps, and sustainable development can be acquired through improve less proper steps. In this case, step 4 and step 7 should be focused, if the sustainability is to be improved.

Summary of the Chapter

This chapter shows the assessment of Korean high-rise housing development by using the EIAHA, the assessment tool described in the previous chapter. The result shows that there are great differences between the value of each step, that lead to many people think carefully for the future development. The results show that there are great differences in the evaluation of each step, raising issues which need careful thought about future developments. It is important to achieve a balance, to ensure environmentally friendly buildings and achieve a sustainable future.

Both Step 1 and Step 2, in the area of passive design and insulation/ventilation, rank 'Medium' according to the assessment. People's desire to have as much sunshine in their homes as possible has stimulated the development of passive solar designs in residential buildings, which gives a good result of the assessment of Step 1 and 2 of EIAHA. Due to a wide range of temperatures throughout the year, Korean people have found ways of coping with difficult weather conditions. This tradition has continued into modern housing development, with apartments facing south to receive winter sun and to avoid summer sun. The open plan of a living-dining area can help cross-ventilation in summer, while double-glazed windows can keep the heat in in winter. A certain width of balcony areas on both front and rear faces of an apartment is especially important to keep or to lose the heat inside, according to variable seasonal requirements. However, insufficient thickness of thermal insulation and absence of preistallation of glazing to the balcony areas ranks both steps as "Medium" rather than "Good".

In the area of building materials, Step 3 (ecology and health) ranks 'Medium', and Step 4 (the materials' embodied energy) ranks 'Bad'. While the ecology of building materials and health issues have both been considered, the importance of embodied energy of building materials has not yet been recognised. Apart from various research topics on energy-saving for building operations in Korea, research on the embodied energy of building materials is hard to find. Just like energy-saving strategies for heavy industries such as car, ship or steel manufacturing, embodied energy for building materials should be considered in future housing developments.

In terms of a heating system, both Step 5 (heating mode) and Step 6 (operation of heating system) rank 'Good' with a high score. Development of an energy efficient heating system has changed the heating mode from an individual boiler system to district heating systems with combined heat and power. This change makes both the result of Step 5 and 6 very high score. For even better score, change of fuel and reduction of complaints from residents are suggested. In order to reduce complaints concerning individual heating bills in the district heating mode, careful design of thermostat and control equipment should be considered.

While Step 8 (management system) ranks 'Medium', Step 7 (building life) ranks 'Bad' with the lowest points according to the assessment. To reduce energy consumption and pollutant production, a strategy for the longer life of building structures is an essential part for the sustainable environment. However, Step 7, the life of building, has the lowest points in EIAHA. Since the life of apartment buildings is too short, a proper management system for apartment estates has been developed. Careful design criteria on the selection of materials and construction methods in addition to a well-established management system will help to get more points in both Step 7 and 8.

The issues mentioned in this chapter interrelate with each other, and efforts towards a solution are suggested to have a good balance between Steps. While the items ranked 'Good' and 'Medium' confirm steadily improving standards, further attention to those assessed as 'Bad' (embodied energy of building materials and building life) is urgently needed. In order to find ideas, attempts to improve the global environment in the United Kingdom, Hong Kong and Singapore will be investigated in Chapter 6. Finally, in Chapter 7, a future sustainable Korean high-rise apartment development idea will be suggested, focusing on energy efficiency throughout the life-cycle of apartment buildings.

References and Notes

Those * marked after a number are books or papers written in Korean. The name of a book in Korean is shown at the end of the Bibliography.

1 See note in Chapter 3

2 Victor Olgyay, *Design With Climate - Bioclimatic Approach to Architectural Regionalism*, Princeton University Press 1963.

3 K-value (unit: kcal/$m^2h°C$) is a thermal transmittance. In UK, U-value (unit: W/m^2K or W/m^{2}°C) is widely used. Since 1 W = 1 J/sec = 0.86 kcal/h, 1 U-value = 0.86 K-value.

4 This area division will be described in chapter 2 with a map of Korea.

5 * Bang-Yeol Park, *Thermal Environment Planning for Residential Buildings*, PhD Thesis, Dong-guk University, 1989.

6 Floor paper is a large, thick slab of laminated paper lacquered with bean oil, and is moisture proof. It is used for the floor with an underfloor heating system in almost every housing unit in Korea, whether houses or apartments.

7* KNHC, *Housing Construction Cost Analysis*, Korea National Housing Cooperation, 1994, pp 209 - 211.

8* KNHC, *Housing Construction Cost Analysis*, Korea National Housing Cooperation, 1994, p 38.

9 The chosen apartment building is a standard apartment building for KNHC (Korea National Housing Cooperation). This is used at any place where required. Total floor area of this building is 7168.91 square metre and the height is 43.9 metre. Total volume of the building, therefore, is 314,715.15 cubic metre. When calculated the area of individual unit (in this case 59 square metre), balcony area is not included. If it is included, the area of each unit will be around 70 square metre.

Current exchange rate of the Korean Won and UK Pound(£) is around 1250 (in the middle of 1995), whilst the Korean Won tends to become stronger against pound. The value for this table is £1 = Won 1250.

10* Daily Newspaper, *Hankook Ilbo*, 13th February 1996

The average price of land in Korea is nearly similar to that in Japan, whose land is some of the most expensive in the world. If we are concerned with GDP, where Japan is about four times higher than Korea, the load for land price in Korea is around four times that of Japan. Moreover, the price per square metre of land in Seoul is 384 times that in Kangwon Province, one of eight provinces in Korea. With the total money for land in Seoul, which occupies only 0.61% of the state, 86% of the national land can be bought.

11 Cement brick is made by sand, gravel and cement. It is called concrete cement in UK.

12 * Daily Newspaper, *Chosun Ilbo*, 20 November 1996.

13 The conversion of the volume to weight is based on this book; Alan Everestt, *Materials*, Longman Scientific & Technical 5th edition 1994. In this book, bulk density (kg/m^3) are in the Table 1.1 (page 6) for common materials. The values of bulk density (kg/m^3) for this study are;

Concrete: 2260	Cement Brick: 1700	Hardwood: 769
Softwood: 513	Plywood: 513	Mineral wool: 120
Glass wool: 128-136 (132)	Plastic Insulation: 16-24 (20)	Glass: 2520

14* Hanyang, *Monthly Management bill Statement*, Hanyang apartment estate in Pundang, 10.93 to 10 94.

15 See Appendix 2 and 3 for details

16* Nam-Ho Lee et al, *A Study on the Improvement of Apartment Heating Installations Coupled with District Heating Systems*, Korea Institute of Energy Research, 1993, pp 90-95.

17 Ministry of Energy and Resources, *Improvement of Efficiency of Apartment Building Heating System*, 1990, p5.

18* KDHC, *Korea District Heating*, Korea district heating Corporation, 1994, pp 18-19.

19* KDHC, *Korea District Heating*, Korea district heating Corporation, 1994, pp 3 - 9.

20* Nam-Ho Lee et al, *A Study on the Improvement of Apartment Heating Installations Coupled with District Heating Systems*, Korea Institute of Energy Research ,1993, pp 97-98.

21* Nam-Ho Lee et al, *A Study on the Improvement of Apartment Heating Installations Coupled with District Heating Systems*, Korea Institute of Energy Research, 1993, p 10.

22* Hyun-Kap Song et al., "Origin and Evolution of the Korean Traditional Ondol and the Direction of New Ondol Development", *Chung pook University Energy Research Journal*, No 8 1992, pp 1-16.

23* Myeong-Seok Yeo et al, "A Study on the Historical Changes and Evolution of Traditional ONDOL", *Korea Architects' Institute Journal Report*, January 1995, pp 93-104.

24* B.I. Park et al, "The Historical Changes of ONDOL", *Air Conditioning Institute Journal Report*, December 1995, pp 613-627.

25* Seong-Wan Kim, "Ondol and Sensation of Temperature of Korean People", *Housing*, November 1994, pp 163-174.

26 Superintendent's office

27 Case apartment groups in Pundang new town

A group (33 blocks, 2419 units) has 6 officers, 12 technicians, 10 electricians, and 92 guards.

B group (15 blocks, 996 units) has 4 officers, 7 technicians, 7 electricians and 58 guards.

28 An examination for expert manager has been taken in every 2 years since 1989

29* Chul Koh et al, *Trends of Rebuilding Apartment Buildings and Their Extension of the Life*, Ministry of Construction, 1994, pp 43-45.

30 Superintendent

31 Actually, banks near each apartment group carry out the job as agencies.

32* Jae-Sun Yeom et al, *A Plan for Rationalisation of Apartment Management*, KNHC, 1985, p29.

33 It is mainly for the managers' salary

34 Total floor areas are 83953 PY (227,045 square metre), so the cost of these fixed management fee per PY is 1668 won (£1.33) [1 PY is 3.3 square metre].

The size of each unit of flat is from 12 PY to 79 PY, majority of the flat is 50 PY. The monthly fixed fee per unit per month is from 20,000 won (£16.00) to

131,770 won (£105.40), with the majority of the flat unit at the price of 83,400 won (£66.72) In addition to this amount, heating, hot & cool water and electricity fee is included according to each unit's amount used

35* Beom-Ik Hwang et al, *An Examination in Apartment Management in accordance with Higher Conversion*, KNHC, 1993, p28.

36 Insurance for fire

37* Bong-Rae Kim et al, *An Examination in Deterioration Condition of Apartment Buildings*, KNHC, 1986, pp 9-11

38 Reginard Lee, *Building Maintenance Management* - Third Edition - 1987, P5.

39 Increased land price is a good example.

40* Chul Koh et al, *Trends of Rebuilding Apartment Buildings and Their Extension of the Life*, Ministry of Construction, 1994, pp 73-74.

41 In the case of the previous model apartment the amount (2,807,000 won) comes from 3/100 of the sum of life maintenance fee (41,514,000 won), heating and hot water fee (1,019,250,691 won), and repair-maintenance fee (215,923,077) divided by 12 (month).

Chapter 6

High-Rise Apartment Development in Other Countries

Different political, economic, cultural and social situations have led to different housing development methods in different countries. Western countries, which already had experience of economic expansion and industrial revolution in the last century and early this century, underwent massive housing construction in the form of high-rise buildings a few decades ago. The United Kingdom, one of the leading countries of this industrial revolution, built many high-rise apartments (flats and maisonettes) in the 1950s and 1960s. This early stage of high-rise apartment construction left many critics and lessons for present developers and designers at home as well as for those in many other countries who are developing or preparing high-rise apartments. The development of high-rise apartments and current situation in the United Kingdom is assessed in the first part of this chapter.

The second part of this chapter deals with high-rise apartment development in East Asian countries, Hong Kong and Singapore, which have experienced similar economic conditions as Korea in the late 20th century. Influenced by western technology, these countries have enjoyed enormous economic growth for around half a century after the second world war. Economic change in Hong Kong and Singapore has also influenced life styles. Life in high-rise apartments has become natural, while it was hardly to be found just half a century ago in these countries. The success of high-rise apartment development in Hong Kong and Singapore, which has lessons for Korean development, is assessed as well as their problems.

In the last part of this chapter, high-rise apartment development in Korea, the United Kingdom, Hong Kong and Singapore are compared. The comparison is done in terms of sustainability, as described in Chapter 4, and will be a vital source for suggestions for future Korean high-rise apartment development as a conclusion of this thesis in Chapter 7.

6-1. British Development of High-rise Apartment Construction

6-1-1 High-rise Apartments in the United Kingdom

In the United Kingdom, large-scale and multi-storey housing appeared at the end of the World War I. Many small dwellings of the nineteenth century which were deficient in structure as well as in planning and design turned into 'slums', which lead to public concern in the early twentieth century. After World War II, the housing problem was even worse because of the huge demand for new dwellings, in spite of massive construction in the inter-war years. During the inter-war years, over one million public houses were built, 30 per cent of all new dwellings. Public housing built in the period between 1945 and 1969 constituted almost 60 percent of total housing construction, reaching over four million dwellings. Within public housing, almost two-thirds of total public housing output in Britain between 1945 and 1979 was detached dwellings, in vast suburban developments. About another 20 percent were three to five storey low-rise apartments (flats), and high-rise apartments made up only the further 20 percent of public housing.[1]

The high-rise apartment (usually called tower blocks) appeared as a solution for modern housing, identified as the provision of sunlight and fresh air, green space and hygienic living conditions. This form of housing maintained population density which cities required to maintain local amenities, as well as providing the inhabitants with conveniences such as indoor toilets, hot and cold running water, central heating etc., that were so lacking at that time. High-rise apartments spread to most big cities in the

United Kingdom, with the sudden tendency of a great shortage of land within city boundaries. Some of them reached heights of up to 30 storeys, which were at the time the tallest residential buildings in Europe. The number of housing units in tower blocks accounted for 75 per cent of all housing completed between 1961 and 1968, while those of 1945 to 1958 were only 5 per cent of the total.[2]

By the early 1970s developers had built high-rise apartments as a quick way of providing for the massive requirement with limited urban land available and short finances. The buildings vary in construction technique, shape, size, style of building, heating and other services, unit size and layout. It is difficult, therefore, to find typical apartments among high-rise blocks. Most of the accommodation was in the form of one or two bedroom apartments.[3]

However, the widespread enthusiasm for these high-rise apartments during the 1960s and 1970s changed into an equally widespread dislike of them, during the next two decades. Their bad reputation sometimes comes from their simply being considered as the obviously wrong solution to the housing problem, but it is not that simple, since the attitude of residents towards dwellings always changes. A measure of satisfaction with the new housing and its high standards with their internal bathrooms, as in luxury apartments, transformed to be an average and then minimum requirement.[4] Increase in criminal action within an estate of tower blocks has added to the bad reputation of high-rise apartments.

High-rise blocks recently (1991) accounted for 5% to 6% of public-sector housing in the United Kingdom. Many of these blocks are now more than 25 years old and need major refurbishment. Many buildings are required to be demolished and rehoused as far as costs alone are concerned. A refurbishment package reassuring energy-efficient measures could be a worthwhile option, but in relatively few cases has it been undertaken.[5] The age of high-rise apartments in the United Kingdom in 1988 is shown in Figure 6-1. The figure indicates that there has been a noticeable reduction in high-rise apartment construction since the 1980s.

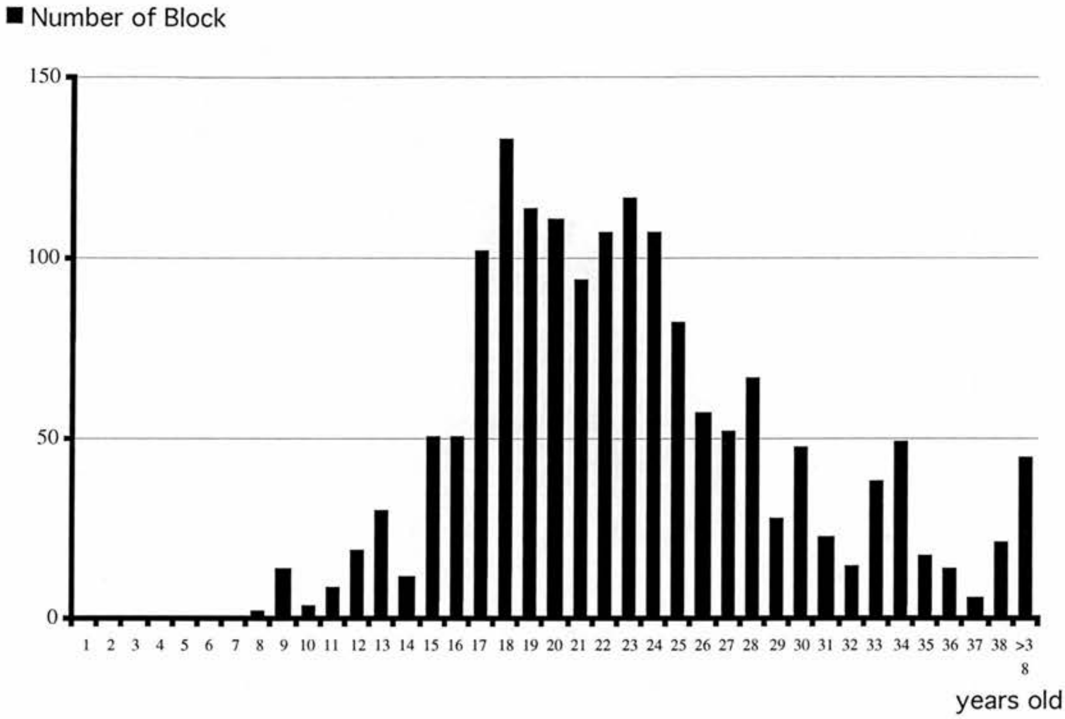


Figure 6-1. Age of High-rise Apartment Buildings in the United Kingdom in 1988

Source : M J B Trim, **Improving the Energy-efficient Performance of High-rise Housing**, BRE Report IP 4/91,1991, p2

Energy consumption related to buildings, one of the biggest issues for the sustainable environment within the construction industry, is enormous, and CO_2 production, as a consequence of energy use, surpasses any other part of industry, in the United Kingdom. Energy use in buildings accounts for almost 50% of the emissions of carbon dioxide (CO_2) which amounted to 579 Mt CO_2 (158 MtC) in 1990. Research in the Building Research Establishment (BRE) has shown that there is a potential to reduce the UK's CO_2 emissions by 12-17% through the use of cost-effective energy efficiency measures in buildings. Recently there has been some attention paid to the embodied energy, as well as information about energy used in buildings throughout the United Kingdom.[6] The target the Royal Institute of British Architects (RIBA) sets for the sustainable environment, for example, is that 'RIBA members should support the goal of reducing carbon emissions arising from building in construction and use by 30 per cent against 1990 levels by 2020'.[7] This target will certainly be applied to dwelling buildings, and especially to high-rise apartments as well.

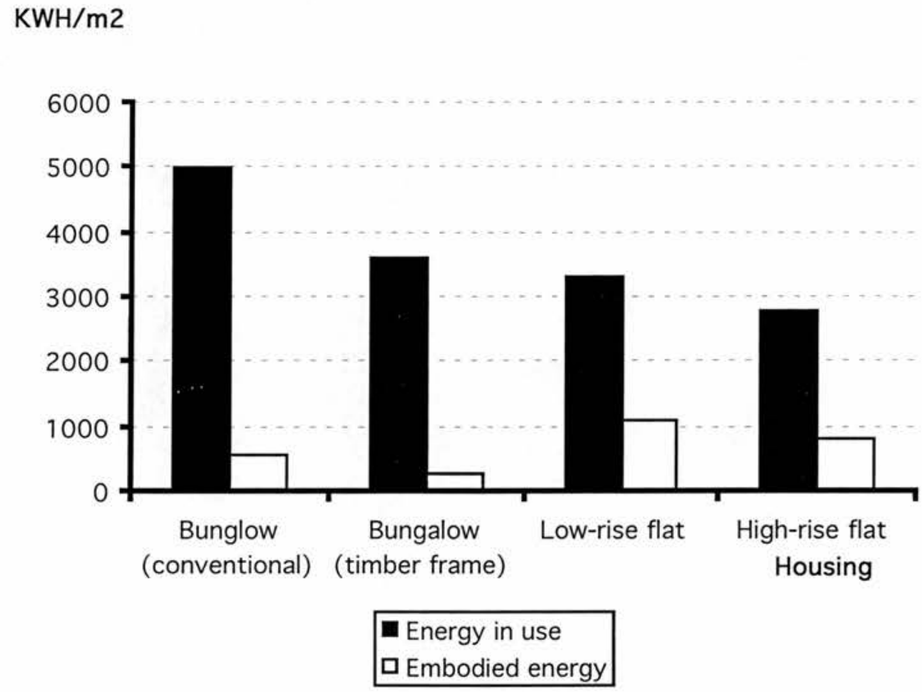


Figure 6-2. Embodied Energy and Energy-in Use over a 25 Year Life

Source: John N. Connaughton (1992) based on Garnes & Rankin (1975)

Energy is consumed in producing buildings (embodied energy) and in operating buildings (energy-in-use) as shown in Chapter 4. The ratio of energy use in both categories differs according to the building type or the construction method. The relative amount of energy consumed in both producing and operating buildings for four different dwelling types in the United Kingdom over an assumed building life of 25 years is shown in Figure 6-2. Although it is difficult to say that these figures are based on the same conditions such as equivalent thermal standards, these may be a rough guide for considering the importance of both embodied energy and energy-in-use. Although apartments need less energy for operation than houses, the former need more embodied energy than the latter.

Recent consolidated thermal standards will have reduced the energy-in-use figure substantially, while the embodied energy values will have increased as more energy intensive material is used to achieve improved thermal performance. Given that major refurbishment cycles are often as frequent as 10 to 15 years for some building types such as high-rise apartments, the embodied energy value of these buildings may be almost as high as the energy used in occupying them over their real life-cycle.[8] This refurbishment frequency is probably unrealistic in practice, that leads to worsen the condition and the reputation of the building.

6-1-2 Efforts for Sustainable Development

Since there are only a few examples of efforts for sustainable development for high-rise apartment buildings, the efforts taken here are mainly from issues of general dwelling buildings.

Since the 1980s, new buildings in the United Kingdom must meet more stringent regulations for energy efficiency. Most of the Building Regulations have been retained from 1992, but part L (Conservation of fuel and power) and part F (Ventilation) of the Building Regulation, which relates to energy saving, was revised in the 1995 Edition in England and Wales. U-values in most areas of building components were consolidated. The U-value for roofs is required to be at 0.20 - 0.35 W/m^2K for dwelling buildings. Windows, which are most responsible for heat loss, are restricted to a large degree. The U-value for an average glazed area should be 3.00 - 3.30 W/m^2K, previously 5.70 W/m^2K in the Building Regulations of 1990.[9] These requirements represent the average of the U-value of doors and any rooflights as well as the windows. The requirements will only be met if the area of the windows, doors and rooflights does not exceed 22.5 percent of the total floor area of the house or flat.

Average U-value can vary according to the size of the window. In the case of SAP 60[10] or less, average U-value is required to be at 2.0 W/m^2K if the total area of windows and doors is 37 percent of the floor area, with 3.0 W/m^2K at 22.5 percent and 4.0 W/m^2K at 16.0 percent.[11] These consolidated regulations require initial excess costs, but will break even over a certain period. For instance, the payback period of mineral wool for loft and cavity wall insulation in the buildings is less than three months.[12]

Table 6-1. U-values of dwelling buildings in 1990 and 1995 (England and Wales)

Element	U-values (W/m^2K) 1995 SAP rating 60 or less	1995 SAP rating Over 60	1990
Pitched roofs	0.20	0.25	0.25
Room in a roof	0.20	0.35	0.35
Flat roofs	0.20	0.35	0.25
Exposed walls	0.45	0.45	0.45
Exposed floors	0.35	0.45	0.45
Ground floors	0.35	0.45	0.45
Semi-exposed walls & floors	0.60	0.60	0.60
Average of glazed areas	3.00	3.30	5.70

Source : Eurisol, **Simple Solutions to Part L**, Eurisol, UK Mineral Wool Association, 1996

Another important element for reducing energy use and CO_2 emissions comes from substitution with materials of lower embodied energy, recycling energy intensive materials, designing to minimise the quantities of material in components and whole buildings, and designing for longevity and reducing refurbishment and replacement frequencies.[13] Current research shows the comparison of building components which have the same or similar role. Among building components, energy use and CO_2 emissions from insulation materials are more easily compared. In general mineral fibre insulants embody substantially less energy and CO_2 emissions than polymeric ones for an equivalent thermal performance. Comparison of embodied energy and CO_2

emissions of insulation materials for an equivalent thermal performance is shown in Figure 6-3.

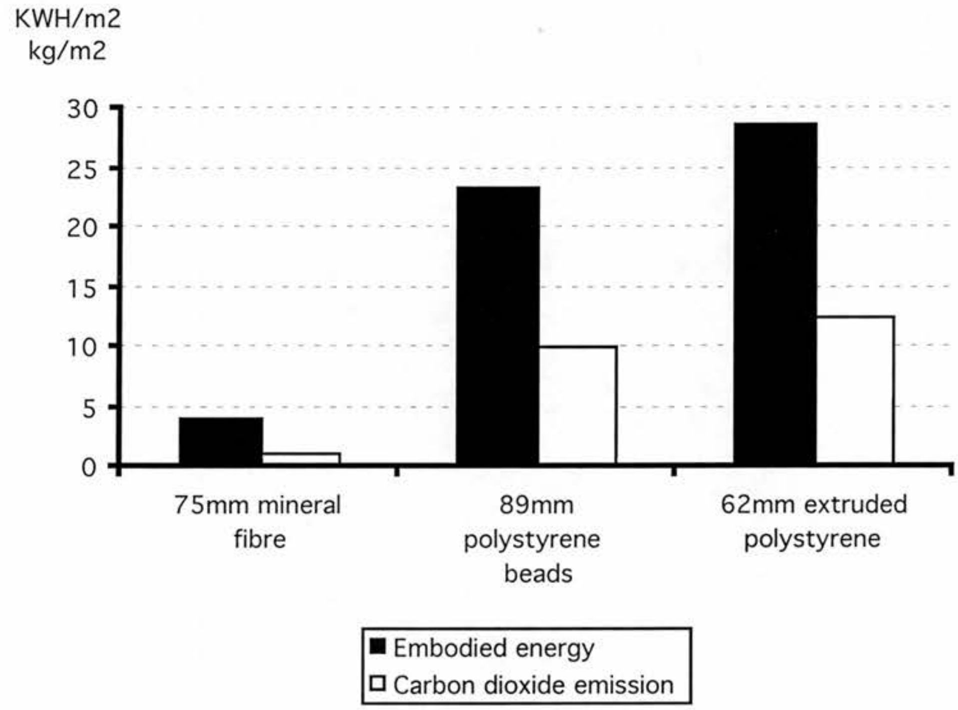


Figure 6-3. Embodied Energy and Carbon Dioxide Emissions of Insulation

Source : David Butler and Nigel Howard, 1992

In the same way, the preferences in terms of embodied energy have been produced recently and those suggested in the context of British houses by Barrie Evans, as one of the examples, are in Table 6-2.[14]

Although not so many cases have been found recently, refurbishment of high-rise apartments are one of the current issues for construction industries in the United Kingdom. The potential for energy efficiency measures as part of the standard refurbishment of high-rise buildings is enormous. The savings in energy through refurbishment are of obvious benefit to the tenants as they enjoy increased comfort with lower fuel bills and less worries against condensation and related problems. The landlord can also have a benefit through reducing void letting, which is one of the reasons for vandalism in some high-rise blocks. An undesirable block can be turned into a desirable one, with fewer tenant complaints and social problems. In addition, complaints will be removed because the flats are no longer difficult to heat to satisfactory room temperatures at a price the tenants can not afford to pay. A good example of an energy-efficient refurbishment is a high-rise block on the Blades Rise Estate owned by the Sandwell Metropolitan Borough Council. The fabric of the building has been improved using internal insulation on the external walls. Other improvements include a new all-electric heating system, double glazing and draught-stripping.[15]

Table 6-2. Preferable building component in terms of embodied energy

Component	Preferences
Frame and Floors	Structural masonry and timber floors rather than frames and concrete floors are to be used where possible. But here, precautions for partial collapse require two-way spanning concrete floors.
External Walls	Masonry is a good choice, though not dramatically better than others. In terms of embodied energy and economy, solid concrete blocks are preferable to solid brickwork.
Roofs	Pitched timber and tile roofs came out better than steel-framed and much better than flat concrete with asphalt.
Internal Walls	Sturdy and simple, demountable partitions came out best.
Internal Doors	Hollow-core doors have least embodied energy, followed by softwood or hardwood solid-core doors.
Windows	Double-glazing pays for its extra embodied energy over single-glazed in about a year. Some high-performance glazing systems may never pay back the extra embodied energy.
Insulation	Cellulose fibre from recycled newsprint is to be used in the roof. Heat loss from ventilation and window transmission overwhelms any further savings to be made from insulation thicker than, typically, 150 mm.
Floor Finishes	Carpet tiles have high-embodied energy both because of their manufacture and their typically frequent replacement.

Source: Barrie Evans, **Counting the Global Cost**, the architects' journal, 24 February 1993, p57

Another main effort for sustainable development is to establish an environmental standard for housing development in the United Kingdom. There are various environmental standard award reports recently which are used for the assessment of various types of buildings. A recent example for new homes made by the BRE[16] is shown in Table 6-3.

Table 6-3. The Environmental Standard Award for New Homes the in the United Kingdom

	Mandatory	Optional
Global issues and use of resources	* CO2 emission rate equal to or less than a maximum allowable value which depends on the floor area of the dwelling * All insulants with ozone depletion potential of 0.10 or less * All solid timber from all managed, regulated sources, or suitable re-used timber * All timber panel products from well managed sources or suitable re-used timber * Storage containers for recyclable household waste	* CO2 emission rate equal to or less than a maximum allowable value which depends on the floor area of the dwelling * All insulants with ozone depletion potential of zero * Low-energy lighting * Provision of gas cooking point * At least 50 percent recycled/re-used material in roof covering * At least 50 percent recycled/reused materials in walls or floor * Demolition materials for fill and hard core * Timber frame construction
Local issues		* Ecological damage to site minimised * Re-use of existing site * Ecological value of site enhanced * WCs with purpose designed maximum 6-litre flush volume * Rain-water butt
Indoor issues	* Formaldehyde emissions minimised; timber only treated when necessary and always treated industrially prior to use; no asbestos and no added lead in paint	* Level of airborne loose fibrous insulation material minimised * Provision of house log book * BS 8206: Part 2 Daylight criteria met in kitchen and habitable rooms

Source : Josephine J. Prior and Paul B. Bartlett, **Environmental Standard - Homes for a greener world**, BRE Report , 1995, p5

6-1-3 Problems of Housing Development in the United Kingdom

Apart from well-established regulations in the area of thermal insulation and lively research on embodied energy of materials, the areas of passive solar design and heating systems for improving energy efficiency have not been widely recognised in the United Kingdom. Whilst there are only a few good examples of solar design, most housing developments only concentrate on the U-value of building fabric for energy saving. There are rare examples of housing developments which consider the orientation for accepting winter sun or avoiding summer sun. Living rooms and other major rooms should be facing the sun to get a moderate thermal environment with less auxiliary heating from a mechanical heating system. This design strategy may also help people's mental health, through getting bright sunshine at home.

Reducing energy consumption in buildings is a big challenge in the United Kingdom. The energy used for domestic appliances and office equipment in the United Kingdom amounts to about half of total energy demand, while that in Korea is just around one third. The case of energy-related CO_2 emissions is similar.[17] One of the reasons will be that heavy-energy industry such as steel production, ship and car manufacture and chemical industries are not popular in the United Kingdom, while most economic activities in Korea depend on these energy-intense industries. A more important point, however, is that buildings in Britain require more energy than those in Korea, mainly for heating, although the temperature in Britain in winter is higher than that in Korea. One reason is that many residential buildings are quite old, which require more energy to operate than new ones, because of less efficient insulation. Concerning high-rise blocks, most of them are now more than twenty five years old and need major refurbishment.

Most heating systems in the United Kingdom are controlled by individual boiler systems or a fire place. In terms of heating sources, the most common form of primary heating for high-rise apartments in the UK is electricity (56 percent), ahead of gas (32 percent), solid fuel (7 percent) and oil (2 percent). These have all proved to be adequate sources of heating in the past, but heating appliances, especially for their efficiency, adequacy and reliability, have become a great concern among housing managers and residents. Some blocks still use electric underfloor heating dating from the 1960s. Such systems are expensive and allow little user control, and so they were found to be unpopular among the tenants. Later electric systems, such as storage radiators, performed better on all counts and were more popular.[18] Recent apartments tend to have gas central heating, which is good for energy efficiency, but district heating systems adopting combined heat and power are strongly recommended, which will provide heat and electricity for whole cities or towns, removing individual boiler systems.

6-2. High-rise Apartments in Hong Kong and Singapore

6-2-1. Characteristics of High-rise Apartments in Hong Kong and Singapore

Unlike most western countries where high-rise apartments have fallen out of favour, those in Hong Kong and Singapore are accepted and even appreciated.[19] Hong Kong has a population of around 6 million in about 1,076 square kilometres of land area. The Singapore Republic, situated almost exactly on the Equator, is a small island of 625 square kilometre and a population of three million. Both countries have successfully managed housing problems by using strong governmental organisations; the Housing Authority in Hong Kong and the Housing and Development Board (HDB) in Singapore. Over half of the population in Hong Kong, around three million people, live in public housing,[20] and about 87 per cent of Singapore population live in HDB apartments,[21] in 1993.

The Hong Kong Housing Authority (HKHA), evolved from three earlier official bodies, the former Resettlement Department, the Low-cost Housing Scheme under the former Public Work Department, and the former Housing Authority, and is 'responsible for advising the Governor on matters relating to housing and for the planning, construction, management and co-ordination of all aspects of public housing and associated amenities.'[22] Hong Kong's public housing programme originated in December 1953 when one of the large squatter areas in Kowloon was burnt by fire, and the Government was faced with rehousing 53,000 homeless people. Since then the HKHA has housed 2.5 million people in a stock of 790,000 apartments by 1993. In 1981, for instance, some 56,000 housing units were built in Hong Kong, about half the total for the whole of the United Kingdom. Most of these were built for the Hong Kong Housing Authority and were virtually all high-rise. However, there were still 163,000 families on the waiting list for housing, 150,000 families living in squatter huts and 1000 new people arriving every week in 1982.[23] In 1992, the expenditure on new developments was £500 million and it is intended by 1999 that the total stock will reach one million apartments, including the redevelopment of older estates.[24]

Hong Kong's public housing accounts for a third of the government's annual expenditure and suffers very little crime or vandalism, even though the form of the housing is similar to that of Western countries where it has been blamed for causing criminal activity. Efforts for reducing the anonymity of management, increasing the involvement of residents in the operation and maintenance of their buildings, and encouraging people to improve and buy their units can make life in public housing much more tolerable, regardless of its location. Similar buildings, obviously, do not draw out similar behaviour, but more importantly, others such as social, cultural, and economic factors play a vitally important role in people's response to public housing. The success of high-rise housing prompts us to qualify the Western condemnation of high-rise, large-scale housing projects. Given changing circumstances, what works in Hong Kong might one day work in other countries.[25]

Hong Kong has developed as a unique city. Despite its being so close to mainland China and having a predominantly Chinese population, Hong Kong's geography and history have resulted in a very un-Chinese city. Situated on an island with numerous peaks, steep slopes and valleys, the city grew from a relatively unimportant seaport occupied by the British at the end of the 19th century to one of the most densely-populated, economically and commercially vital cities in the world. Although a large majority of the refugees who flowed into the city over the last 30 years came from China, in which traditional Chinese courtyard-houses predominated, the pressure for huge numbers of houses and the inherent lack of space for housing led to a strong dependence on high-rise construction for housing. This type of apartment units, developed in the West, has nothing in common with indigenous dwellings on the mainland.[26]

Hong Kong's housing estates are integrated developments containing covered shopping complexes, markets, schools, community facilities and local transport links. An important element is the provision of covered footpaths linking each block with the major facilities. These provide a sheltered pedestrian route during periods of heavy rain or hot sun in typical Hong Kong's summer months.[27] Along with the expansion of the city, new towns have been developed. For example, Tung Chung new town, as part of the plan to build Hong Kong's new airport at Chek Lap Kok, are taking shape recently. Several sites are formatted through reclamation within new town, in which public housing will appear. The project will comprise both a Home Ownership Scheme and rental apartments, and is due to be completed in mid-1997 together with associated commercial, welfare, and educational facilities, all in time for the planned opening of the new airport.[28]

Singapore, which has found another effective solution to its housing problems in the remarkably short time of just a few decades, is one of a very few examples. Although there are many attempts to address housing problem, examples of successful programmes, or even projects, have been few throughout the world.[29] The solution of the problem in Singapore has been reached through accommodating people in high-rise apartments mainly built by the Housing and Development Board (HDB). One of the most important factors which has contributed to the success of Singapore's housing programme has been the firm commitment of the government. Governmental policies have been implemented towards 'meeting specific prevailing pressing needs, development and institution of an appropriately staffed and empowered agency, promulgation of requisite legislation and adequate financing'.[30]

Singapore is fast gaining an international reputation as a tropical garden city. It is clean and green, and the envy of many neighbouring countries. The modern garden city developed in step with the urgent need to solve a major housing problem in the mid 1960s, when urban areas were over-crowded and disease ridden. The British initiated the first new towns with the establishment of the Singapore Improvement Trust (SIT) and although this only succeeded in building 20 per cent of the nation's total housing requirements, it provided a background of experience for its successor, the Housing Development Board (HDB).[31]

The Housing and Development Board (HDB) in Singapore was established in 1960 as a statutory body under the Ministry of National Development. It has extensive responsibilities and powers including 'land assembly, slum clearance and re-settlement of squatters, planning and design of estates, construction of housing units and ancillary facilities, sale or rental of units together with the provision of mortgages, maintenance and conservancy of existing estates, and research into social and technical matters relating to housing.' Therefore the main activities of the HDB is the provision of suitable housing for sale or rent to lower and middle income groups, and management of estates. The Board undertakes the normal routine maintenance and repair of services installations, external landscaped areas and general cleaning of common areas and accompanying facilities.[32]

Dwelling units built by the HDB were 11,337 in 1991/92 (April 1991 - March 1992), and 16,564 in 1992/93 (April 1992 - March 1993). Total dwelling units under management by 31 march 1993 were about 643,000 units. Among them, most sold apartments are three or more bedroom apartments, while most rental apartments are one or two bedroom apartments.[33] There were 40,973 new requests for apartment in 1992/93 and a total of 20,552 apartments were sold during the year. Five-room apartments made up 41 percent of the sales, with Executive apartments accounting for 30 per cent and four-room apartments, 24 per cent. These were the apartment units that were completed in 1992/93 and they included larger apartments made available under the conversion programme.[34] The conversion scheme, introduced on 1 January 1993, allows owners of three-room and smaller apartments to purchase an adjoining three-room or smaller apartment for conversion to a larger one. In this way, they can get to enjoy a bigger living space without having to move out of their estate. [35]

To meet demand for new flats, the HDB further increased its building programme to 30,000 units for 1994 and thereafter for each year. Future housing development will centre on the northern region. An HDB annual report suggests that it will not just be quantitative targets that the HDB has to meet. Home buyers include both a fast growing middle-class population seeking more sophisticated design features, and lower income groups who will continue to need housing priced within their financial abilities. The HDB's challenge is to provide housing that meets this 'wide spectrum of buyers.'[36]

6-2-2. Lessons from High-rise Apartment Development

The successful accomplishment of solving housing problems in these two countries gives us lessons for the future development of high-rise apartment construction in other countries, especially those with dense populations. The lessons and problems described here are mostly extracted from governmental reports, the Hong Kong Housing Authority Annual Report 1992/93 and the HDB Annual Report 1991/92 and 1992/93.

First of all, both authorities have tried to improve the quality of their estates to meet the requirement of residents, as well as to achieve housing quantity targets. The Hong Kong Housing Authority (HKHA) is continually making changes to improve quality and is producing better homes as a result, with better facilities and a greener environment.[37] In Singapore, the Housing and Development Board (HDB) introduced the Residents Priority Scheme to give resident applicants a higher success rate in the ballot for apartments in their own estates. By making it possible for more of them to remain in their own home towns, community ties will be kept alive over the years. The Design and Build Scheme, launched in 1991, provides HDB home buyers with an opportunity to express their desire for greater variety in housing design. The involvement of the private sector in this scheme will further enhance the range of housing designs. To help HDB neighbourhood shops better with their share of the retail business, the 'Sale of Tenanted Shops Programme' was introduced. By giving retailers the opportunity to own their shops, they can upgrade their operations and become more competitive.[38]

The environmental effects of constructing and maintaining high-rise apartments in Hong Kong has been taken into account, and efforts for improvements are regularly introduced. For instance, blocks have been checked for design and energy efficiency, for better living conditions. Environmental studies are carried out when necessary for the location of the blocks in layout designs, away from noise generating sources. The use of automated refuse collection systems is pursued, as a new environmental programme. These systems transport refuse from the chutes in domestic blocks via underground pipes to a central collection plant. Refuse is then compacted and removed by lorry. The first of these environmental friendly systems was to be installed for testing at Fanling Area 47B, Phase 1, and was due for completion in August 1995.[39] The HDB in Singapore provides refreshing greenery and landscaped surroundings to enhance its estates, through supplying hundreds of thousands of plants each year to various new towns. The HDB has also embarked on a programme to construct multi-story car parks to free space for landscaping. In support of nation-wide efforts to keep Singapore's urban rivers clean, the HDB has undertaken a programme to minimise pollution to the urban river.[40]

As a result of concern over the depletion of hardwood from the world's rain forests, an assessment has been made of the amount of hardwood used by the Hong Kong Housing Authority. Environmentally friendly materials are being used in the design of landscape features such as pergolas by using softwood obtained from sustainable forests, or other materials. The use of hardwood has been significantly reduced. Alternative types of playground equipment with no hardwood content are being specified, and the use of new materials, such as a composite made from recycled polythene bags, is being considered. Planting has been improved by increasing the maintenance period from one to two years. The result is more cost-effective, longer-lasting planting which will enhance the environment for years to come. Professional material testing services have been introduced to replace the previous term testing contracts. The original contracts were for the testing of main building materials only. The new service, provided by materials consultants in association with local registered testing laboratories, extends the scope of testing to all materials used during construction. As a result, project designers and maintenance staff will be confident that materials specified will meet the required standards.[41]

In Singapore, issues regarding materials have focused on security and the ease of production. The HDB continued to use precast technology to reduce reliance on skilled labour and improve the quality of building components, such as facades, lightweight partitions, parapets, floor slabs, staircases and refuse chutes. The off-site precasting of these components enabled quality to be closely supervised under factory conditions. The HDB has also developed a prefabricated steel reinforcement (PSR) system that links the design, detailing, fabrication and installation of steel reinforcements through standardisation and computerisation. To help maintain stable prices and an adequate supply of essential building materials, such as granite and brick, the HDB operates its own granite quarry and brickwork plant.[42]

In order to sustain or improve the estate environment, efforts have been taken in both cities. In Hong Kong, the approach taken to improve the general environment of existing estates focuses on providing residents with a better living environment today and also looks forward to ensuring a good living environment for the future. This is particularly evident in a number of major improvement programmes carried out. During the year 1992/93, 213 apartment blocks in 30 estates/HOS courts were redecorated. The Wo Che Estate in Sha Tin and the North Point Estate on Hong Kong Island, both located in prominent areas, for example, were redecorated with beneficial impact on their general environment. A programme also began for the extensive environmental upgrading of middle-aged estates now included in the Redevelopment Programme. In the first job under this plan, some HK$ 25 million (around £ 2 million) would be spent on Fuk Loi Estate in Tsuen Wan.[43]

Besides this redevelopment plan, there are periodically planned maintenance and improvement programmes in Hong Kong. These programmes amount to over 90 per cent of the annual maintenance expenditure. The expenditure on maintenance and improvement rose to HK$ 1.46 million (around £ 120 thousand) during the year 1992/93. The comprehensive structural repair programme for older estates continued with 56 blocks being completed during the year. Following reports of defects by tenants, a works programme was started to replace leaking shower trays in a number of linear type blocks. Several other major improvement programmes were also initiated during the year. The programme for the refurbishment of vacant apartments has been substantially expanded and improved standards of finishing and essential services have been introduced. Some 7,200 apartments have been refurbished to these higher standards and this work is continuing. Three building surveying consultancies have been engaged and specific dedicated refurbishment contractors have been appointed to help with this enlarged programme.[44]

In Singapore, the Upgrading Programme of the HDB was launched in March 1992. With the Upgrading Programme, residents of the older estates will be able to enjoy a living environment comparable to the new estates. Through the government's Upgrading Programme, apartments aged 17 years and older will be refurbished. In this way, the existing housing stock will be kept in good condition and brought to the standards of the newer estates. Works on the Demonstration Phase and preparation for the Steady Phase of the programme are well under way. Three types of upgrading packages have been identified for the Steady Phase: Basic, Standard and Standard Plus. The Basic Package comprises essential improvements that provide the best value for money. The Standard Package offers all these essential improvements, plus upgrading of the building facade. The Standard-Plus Package not only has all the items of the Standard Package, but also a space-adding item included. Apartment owners' share of the cost of the Basic and Standard Packages and the standard portion of the Standard-Plus Package is between 10 and 25 per cent of direct upgrading cost, depending on apartment type. For the space-adding item, flat owners' share of the cost has been set higher, ranging from 40 to 80 percent depending on apartment type. As in the

Demonstration Phase, residents will be consulted on the items to be included in the upgrading package. A working committee for each precinct has been formed, headed by the respective advisors to the Grassroots Organisations and comprising grassroots leaders, HDB representatives and architects appointed to design the upgrading package for that particular precinct. To speed up the programme, there are also plans to introduce an Interim Upgrading Programme for apartments between 10 and 17 years old.[45]

6-2-3. Problems of High-rise Apartment Development

Although Hong Kong and Singapore have solved their housing problems successfully through accommodating people in high-rise apartments, there are some side-effects to this victory. In Hong Kong, with existing urban areas already at densities of quite frightening proportions, most of the housing development is going on in a series of new towns, built from scratch at enormous speed and with only the bare necessities of infra-structure. Anything up to 30 storeys above ground in a block has been designed and built with speed and low cost rather than quality in mind.[46] Each new town has been built to cater for 750,000 people housed in multi-storey blocks. These trends have transformed the landscape, with the accumulation of identically tasteless high-rise blocks.[47]

Environmental concern in high-rise apartment development has concentrated on regional pollution and neighbourhood relationship in both countries. Concern over the global environment, such as over global warming or ozone depletion is hardly to be found, although there is an interest in conserving tropical forests in Hong Kong.

6-3. Comparison of High-rise Apartment Developments

As the situations of construction industry differ according to country, solutions for sustainability for high-rise apartment buildings have to be considered in different ways. While maintenance, refurbishment or reconstruction are major issues in the Western countries such as the United Kingdom, fast construction of massive housing units in a relatively short period has the priority in the fast growing Eastern countries. High-rise apartments in Hong Kong and Singapore are now at the stage of moving from quantity issues to quality and maintenance issues, while there are still conflicts between the two extreme issues in Korea. Weather conditions, which are a vital element for energy consumption for thermal comfort, are different from country to country. Locally produced building materials also differ, which makes it difficult to identify a single construction type for a sustainable future.

The comparison, therefore, can only be made where there are options for improving the situation or not. After a rough description of high-rise apartment developments between Korea, the United Kingdom, Hong Kong and Singapore, items of sustainability in each country will be identified as 'Good', 'Medium' or 'Bad'. Main judgement tends to be made by the EIAHA, which was described in Chapter 4. However, the decision will be quite subjective occasionally, where different criteria will be required such as heating load, transfortation of materials, etc. The purpose here is to indicate current situations roughly, in order to figure out the guideline for the future developments. In the last part of each section, there is a table of key issues and their grades, either 'Good', 'Medium' or 'Bad'.

6-3-1. Passive Thermal Design

Accepting energy from the sun is a major element in passive design. In order to get energy from the sun, buildings should have a certain orientation. On some occasions, special facilities for using the sun, such as sunspace, a greenhouse or a balcony, help to control the indoor temperature. Shading devices for excessive energy in summer days or in tropical regions are also used to avoid overheating. Apart from using the sun, it is important to block off heat flow between the inside and outside of a building. By accommodating proper insulation in the building fabric, such as in roofs, walls, windows and floors, appropriate indoor temperatures can be maintained even when the outside temperature is extreme. Proper insulation is especially important when the outside temperature is very cold, but is also useful in hot circumstances if ventilation is well operated.

In the United Kingdom, apart from well-established regulations and research in the area of thermal insulation, the areas of passive solar design for improving energy efficiency have not been widely recognised. Although there are some good examples of solar design, most housing developments only concentrate on the U-value for energy saving. There are rare examples of housing developments, especially for high-rise apartment buildings, which consider orientation for accepting winter sun or avoiding summer sun. Living rooms and other major rooms should be facing the sun to get a moderate thermal environment with less auxiliary heating from a mechanical heating system. Since neither orientation nor balcony/sun spaces are considered in high-rise apartments in the United Kingdom, first step of the assessment is categorised as 'Bad'. Well established U-values helps to grade up to 'Medium' for second step, although lack of ventilation, for the second step.

Passive design items for thermal comfort in Hong Kong and Singapore are quite different from those of Korea and the United Kingdom. Issues for these tropical countries should concentrate on cooling. The proper orientation for these hot countries are south or north, where limited sunshine can enter into the living spaces. Buildings should especially avoid facing West, since the strong afternoon sun can heat up room temperatures to an uncomfortable point. However, there is little concern for the orientation of high-rise apartment designs in these countries, although some cross ventilation for reducing overheating is considered in Singapore. First two steps of the

EIAHA is not entirely applicable for these two countries, because the requirement of the buildings is quite different according to the different weather conditions.

In Korea, the orientation of buildings has long been recognised and developed because of extreme weather condition variations between summer and winter. Plenty of sunshine in winter helps to design South facing buildings, which allow in warm sunshine. South-facing balcony areas in apartment units can be converted to greenhouses in winter, while they prevent the summer sun entering into the living areas. However, standards for insulation materials are not high enough for reducing heating loads, compared to the British case. More stringent regulations for U-values (or K-values) are required. The decision of the assessment is quoted from the previous chapter, as 'Medium' for both steps.

Table 6-4. Comparison of Passive Design

Country	Passive Solar Design	Insulation and Ventilation
Korea	Well established orientation Using balconies as sunspace, but preinstallation of window is preferable Mark -- **Medium**	Need more stringent U-values Window double-glazed. Well designed for cross ventilation Mark -- **Medium**
United Kingdom	Orientation should be a concern Sunspace preferable Mark -- **Bad**	Well established U-values Lack of ventilation for summer but good for long winter Mark -- **Medium**
Hong Kong	Orientation is not so important for accepting sun Careful design is needed for overheating Mark -- **Medium**	Need a least insulation Open floor plan is preferred for cross ventilation Mark -- **Bad**
Singapore	Orientation for avoiding overheating is required Mark -- **Medium**	Balconies are good against overheating inside Well established cross-ventilation Mark - **Medium**

6-3-2. Building Materials

The issues regarding building materials in terms of the environment are divided into two categories in this research. One point is to focus on issues of human health or ecological systems as well as global environmental problems, and the other point is embodied energy for building materials. The importance of embodied energy has been recognised since the security of energy sources has become unstable, and carbon dioxide as the by-product of consuming fossil fuels has proved to have a major responsibility for global warming.

In the United Kingdom, use of materials which affect human health, such as asbestos and CFC brown insulants, has been reduced and will finally be phased out in the near future. However, the use of solvent-based paints is not prohibited, although regulations apply, such as the Control of Substances Hazardous to Health (COSHH).[48] Concerning embodied energy, about 10% of industry's energy consumption, or 5% of the total energy consumption, is used in the production of building materials in the United Kingdom.[49] Embodied energy for apartments is nearly a third of energy-in-use over 25 years, while only a tenth of energy-in-use is required for embodied energy in an individual house.[50] A bright point in the United Kingdom is that there have been worthy studies to find alternative materials for less embodied energy. In the case of insulation materials, for instance, research has found that mineral fibre insulants embody substantially less energy and CO_2 emissions than polymeric ones for an equivalent thermal performance,[51] and there tend to be thicker and therefore have an implication in construction. The grades for both steps are categorised to 'Medium'. There has been much improvement in each step recently in the research, and started to implement in the construction sites.

In Hong Kong, there has been concern over the use of tropical hardwood in the construction industry, because of the recognition of the need for sustainable forests. Policies in Singapore have concentrated on the security of the building materials to prevent sudden shortage or rapid price increase. Research on embodied energy can hardly be found in both countries. Issues of the building materials concerning the global environment in both countries do not have priority over other factors such as the security or price stabilisation of them. The two countries have the same grades for both steps as 'Medium' for Ecology and Heath, and 'Bad' for Embodied Energy.

Health issues for building materials have started to emerge in Korea. The use of asbestos is now reduced, although it will take a certain period until the use of them finally stops. CFC brown insulants will be difficult to use in the near future. Embodied energy figures for construction materials in Korea, however, are not yet well established. Energy concerns for material production concentrate on materials used in heavy industry like car or ship production. Since most recent housing construction is high-rise apartments, embodied energy of materials for housing will be a big portion of the energy figure. The grades taken from the previous chapter are 'Medium' for Ecology and Health, and 'Bad' for Embodied Energy.

Table 6-5. Comparison of Building Materials

Country	Ecology and Health	Embodied Energy
Korea	Commencement of concern over hazardous materials Mark -- **Medium**	No well established recognition Needs to be improved Mark -- **Bad**
United Kingdom	Strict regulations for Asbestos and CFC brown insulants Concerns of paint and wood are required Mark -- **Medium**	Lively research for embodied energy figure Strict regulations are required Mark -- **Medium**
Hong Kong	Concern over hardwood from tropical forest Mark -- **Medium**	Not well established recognition Mark -- **Bad**
Singapore	Materials issues concentrate on security Mark -- **Medium**	Not well established recognition Mark -- **Bad**

6-3-3. Energy Use for Thermal Control during Building Operations

In order to achieve thermal comfort of human beings, mechanical heating or cooling systems have long since been developed. Technology has made it easy to get proper thermal conditions with less energy consumption. Sharing heating devices in a group has made it possible to reduce the amount of equipment. Despite this central heating or district heating needing more careful design for distribution systems, it can reduce the use of energy in operation. Moreover, it can reduce the energy used in making equipment since a number of instalments can be converted to just one. Careful operation of heating mode is also required for the maximum satisfaction and minimum energy use.

The history of the development of district heating systems is relatively long in the United Kingdom, but it is still not popular in society. Most apartments have individual heating boilers to control their own indoor temperatures. Moreover, for high-rise apartments, the electric heating mode is still used in many units with massive energy consumption and production of a lot of carbon dioxide, because of, for instance, inefficient operation. Massive amount of heating bill during long lasting heating period is one of the major complaints for residents in the high-rise apartments. Both steps are, therefore, categorised as 'Bad' in the United Kingdom.

Although heating is required in Hong Kong occasionally, it is not necessary to have a heating installation in an apartment unit. Governmental guides recommend the Energy Efficiency Ration of an air-conditioner when buying a unit. Hot water for domestic use is only produced by individual water heaters in Hong Kong residential buildings.[52] Singapore will never require heating facilities, since the mean temperature in each month is around 30 °C around the year. Although it is more difficult to develop central or district cooling systems than central or district heating systems, it is strongly recommended that these hot countries exploit such systems, as well as developing passive design for solar context. Because of the difference of the weather condition in both countries, it is difficult to apply the EIAHA step 5 and 6 in Hong Kong and Singapore. The grades for these steps for both countries are given 'Medium'.

Recently developing high-rise apartments in new towns tend to use the district heating mode with governmental support in Korea. This mode can save enormous amount of energy compared to the central heating mode or individual boiler mode. Careful design for thermostats and a measuring system are the only, and the most important, elements for improving resident satisfaction. Although there are a few complains on the operation of the heating system, they are a few exceptions. The grades for heating system in Korea is, as shown in the previous chapter, 'Good' in both step 5 and 6.

Table 6-6. Comparison of Heating or Cooling Systems

Country	Heating or Cooling Mode	Operation of Heating/Cooling System
Korea	Widespread use of District Heating mode Mark -- **Good**	Careful operation is required Mark -- **Good**
United Kingdom	Electric heating requiring much energy Mark -- **Bad**	Complaints from residents over heating systems Mark -- **Bad**
Hong Kong	Heating and Cooling is controlled by the residents Mark -- **Medium**	Mark -- **Medium**
Singapore	No need to have heating installations No central cooling devices Mark -- **Medium**	Mark -- **Medium**

6-3-4. Management and Maintenance

Traditionally, the importance of a long-life for a building has been recognised for conserving historical landmarks and for economic preference. One more point has been added recently - the environmental perspective. Constructing and demolishing a building uses massive energy consumption during the process, and the activity requires massive amount of raw materials and produces unwanted waste. It is important to have a stable structure to extend a building's life, but a more important element, especially for high-rise apartments as a collection of individual houses, is to maintain social requirements. Well established management programmes, including a regular repair or maintenance programme, is, therefore, very important.

In the United Kingdom, the physical life of high-rise apartments is relatively long. However, failure of management has led to a bad reputation for them. Whilst a few well managed and properly refurbished tower blocks overcome the problems of vandalism, most of them still suffer from crime within their estates. Deterioration of facilities add up the trends of hatred of the high-rise apartments. The good reputation which they once had can only be recovered through intense efforts to upgrade the quality of the buildings. The grade for building life is 'Good', although that for management system is 'Medium', because of lack of maintenance fund and repair plan

In Hong Kong, maintenance costs account for more than one fifth of the expenditure on new building works recently. There are two significant maintenance management systems to provide improved services to residents - the CARE (for Condition, Appraisal, Repair and Examination) system and the CCMS (Central Control and Monitoring System). The CARE system is a cyclical maintenance system which ensures that all properties are surveyed every six years and that maintenance works are co-ordinated and implemented to provide a 'quiet period' for estate residents before the next cycle of works, whilst the main purpose of the CCMS is to identify quickly any defect in building service installations. In order to check the performance of buildings, the PASS (Performance Assessment Scoring System) - and MASS as its maintenance counterpart - have been in operation. These two systems provide objective data on the performance of individual contractors and assist in selecting contractors for new contracts.[53] In Singapore, old apartments will be refurbished through the government's Upgrading Programme. This programme was initially targeted for apartments over 17 years old, but it is also planned to extend this to those between 10 and 17 years old. The grades for both steps in both countries are 'Good', as the life of buildings is long and the management systems are well established.

In Korea, the history of high-rise apartments can only be traced back for 25 years. Bulk construction of this type has been popular for only 10 years, which means that it is still early to suffer from the problems of old estates. However, because of the social and environmental problems of low-rise apartments whose lifespans are only around 20 years, concerns have recently increased for the extension of the life of high-rise apartments. Regulations for management systems have changed enormously in the last 10 years and will continue to do so in order to extend the life of high-rise apartments. Although the current trends of building life is categorised to 'Bad', future improvement will be expected, since the importance of the building life has been recognised recently, leading to establish proper management system. The last step, therefore, is allocated to 'Medium'.

Table 6-7. Comparison of Management and Maintenance

Country	Building Life	Management System
Korea	The life of current apartments is too short Mark -- **Bad**	Establishment period for management systems Mark -- **Medium**
United Kingdom	The life is long but leaves the requirement of major refurbishment work Mark -- **Good**	Lack of sound estate environments Mark -- **Medium**
Hong Kong	The life is long but leaves the requirement of major refurbishment work Mark -- **Good**	Well managed programme by the government authorities Mark -- **Good**
Singapore	Extending life through adjusting to new requirements Mark -- **Good**	Well established repair programme Mark -- **Good**

Summary of the Chapter

Through the investigation of high-rise apartments in different countries, it is recognised that the buildings with the same idea and form can hardly have the same function or reputation according to the country. Social and cultural identity has affected the success or failure of high-rise apartments. Although the general opinion ranging towards apartment buildings is extreme between the United Kingdom, Hong Kong and Singapore, lessons can be learnt in all cases.

Although high-rise apartments are generally said to be a failure in the United Kingdom, lessons such as strict regulations of insulation for preventing heat flow and research on embodied energy need to be considered. The failure itself can also be converted into a vital lesson for future developments. Careful investigation of management systems can help to extend a building's life, since the physical condition of it is not so serious.

Widespread acceptance of high-rise apartments in Hong Kong and Singapore are an encouragement to other countries which require massive housing units in a relatively short time. High-rise apartments have been rooted firmly into both countries, through efficient control of construction and management by government organisations. Both the Hong Kong Housing Authority (HKHA) in Hong Kong and the Housing and Development Board (HDB) in Singapore are not only responsible for the construction of the apartments but also for their management and maintenance. Variety of design and well-established maintenance and upgrading systems in both countries can sustain the housing type which has got a bad reputation in Western countries.

Comparison of high-rise apartment development between Korea, the United Kingdom, Hong Kong and Singapore in terms of sustainability, provides a rough guide for future development of high-rise apartment. The result is summarised in the following graph. The longest bar (matched to number 3) means the category is 'Good', while the shortest bar (number 1) represent 'Bad'.

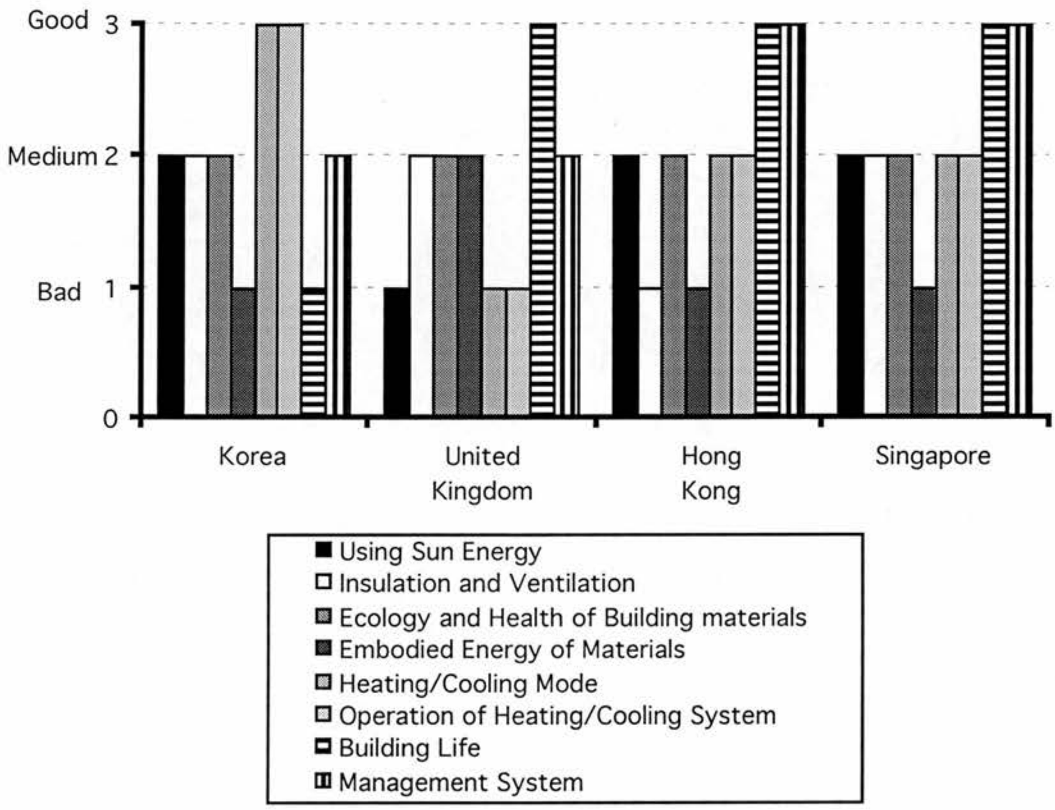


Figure 6-4 Summary of Comparison of High-rise Apartment Developments

This analysis is a basis for future high-rise apartment development for a sustainable society. In the next chapter, as the concluding part of this thesis, suggestions for high-rise development in Korea will be described as one of the solutions for minimising the environmental impact.

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Chapter 7

Proposals for the Future Development of Korean high-Rise Apartments

Korean people have recognised the seriousness of environmental degradation, which is now noticeable mainly due to massive economic growth. Their priorities have shifted from obtaining the economic growth to improving the quality of life and achieving a sound environment. Regional air and water pollution have become two of the biggest issues for citizens, as well as for politicians and administrators. Scientific evidence has revealed the seriousness of climatic change, acid rain and the effects on humans, such as skin disease, and these threats have now been recognised. In addition to people's increased awareness, international and national environmental policies have been affecting most industries, including the construction industry.

As shown in Chapter 5 and Chapter 6, the solutions for high-rise apartment buildings in Korea, in terms of sustainability, are quite different from other countries, not only because of physical conditions, but also because of the social and cultural basis, including political and economic situations. This present chapter seeks appropriate proposals for future high-rise apartment development in Korea, where the situation should be unique with regard to those in other countries.

Solutions for Korean housing development focus on energy conservation and the life-cycle design approach. Concerns for energy saving not only concentrate on energy use during building occupation, but also the recognition of energy use during construction, maintenance or demolition. Without reducing the merits of passive solar design including insulation and ventilation, careful selection of building materials in terms of energy content is strongly recommended. Strategies for lengthening the life of buildings are also important. Redevelopment of old apartments aged only around twenty years, which is now common in Korean housing development, has to be stopped in the near future. If this phenomenon continues it will have an enormous environmental impact, because affordable building materials will become exhausted as well as the energy required for producing these materials, as demolition of old buildings and reconstruction of new buildings will increase enormously. This has further implications for waste problems.

7-1. Energy Saving Strategies for High-rise Apartments

There are three methods of producing energy efficient apartments; (1) by reducing the building's energy requirement, (2) by employing better mechanical heating facilities for energy consumption and (3) by cutting the embodied energy of building materials.

For the first method, designers are concerned about building shape and orientation, insulation of building skin including doors and windows, and proper ventilation for cooling and indoor air quality. This method requires proper understanding of regional climatic conditions and the performance of building fabrics.

More efficient mechanical thermal facilities for both heating and cooling, as a solution for the second target, require less energy consumption, which helps to reduce the cost of energy as well as the discharge of toxic gases. Although architects' understanding of mechanical heating systems does not have to be comprehensive, architects do need to analyse energy consumption for thermal comfort, according to the heating or cooling method. It is also important to consider the energy requirement of each living area, and to put proper facilities into each room.

The last point, material's embodied energy, has been ignored by architects and developers in Korea. When architects think about materials, the priorities for them are price, comfort and life-span of each material. Some modern architects consider the materials' impact on the environment in terms of health and indoor air quality, but few consider the embodied energy.

7-1-1. Passive Heating Strategies for Improving Thermal Conditions

According to Korean tradition, people have a strong preference to have houses facing the sun. This tradition, the orientation of houses, is good for passive solar energy design. It is not only good for absorbing winter sun for passive heating, but also for cooling when accompanied by good ventilation during the hot humid summer. This tradition has continued and has even been improved upon in modern high-rise dwellings. The living room and the main bedrooms in each unit of apartments tend to face south, south-east or south-west, where efficient sunshine can be taken in. Regulations, which have guidelines for the distance between two apartment buildings according to their orientation, stipulate a minimum amount of sunshine for the living areas of apartment units in winter. The open plan living-dining-kitchen design in most apartment units can also help summer temperature control, when people need a good flow of ventilation.

However, the proper orientation cannot always be obtained due to other factors. Community plans for harmony within an estate require a design variety, which can hardly be achieved by arranging rows and rows of the same buildings. The extension of the traditional courtyard is achieved through the enclosed design of buildings in each estate, resulting in the disfavourable orientation of some buildings as regards passive solar design. The responsibility for designing each estate lies with architects and designers. Some estates have certain solutions through landscape architecture or parking plans. The location of shops, community centres and children's playgrounds in each estate can also enhance the master plan by creating a more harmonised community, without reducing the benefits of orientation.

In terms of unit plans, balcony areas, which help to control internal temperatures both in summer and winter are a feature of Korean high-rise apartments, as well as other types of housing. These were originally planned for giving buffer space between private and public spaces, like private gardens for houses or bungalows. This idea has actually occurred to residents who make mini-gardens in the balcony areas. In most cases, however, the original purpose has been transformed into having a greenhouse or thermal buffer zone, through installation of windows around the balcony areas. These trends are very common nowadays, and more than 90 percent of apartment units have their windows around their balcony areas, with the added advantage being passive solar design. However, the proper instalment of windows is not usually established during the process of construction, being instead the responsibility of residents, thus requiring further finances on their part. The argument here is that these should be installed by construction companies during the process of construction. By including this job in a step of the construction process, it would reduce both economic and environmental costs. A new design for high-rise apartment buildings could also be created as windows feature prominently in the appearance of the main facade.

As regards insulation, the regulation still does not cover the proper thickness of insulation or levels of K-value (or U-value), when compared to British standards. Weather conditions in Korea probably need more stringent regulation for insulation than the United Kingdom, since the Korean winter is colder than that in Britain. However, in Korean apartments, most buildings have another layer of wall - mostly comprising of just windows - outside balcony areas. This layer helps keep indoor temperature up, making balcony areas greenhouse or thermal buffer zones. Therefore, regulations should be differentiated between walls with and walls without these balcony areas. Side walls, which usually do not have balconies, comply with more stringent K-values: 0.4

kcal/$m^2h°C$ (U-value: 0.47 W/m^2K) instead of 0.5 kcal/$m^2h°C$, which is still higher than the British regulation (U-value: 0.45 W/m^2K). Regulations for other walls, apart from side walls and walls with balconies, should be added for proper thermal performance.

Along with increasing standards of insulation, it is recommended that designers pay greater attention to details, so as to ensure that the additional insulation is as effective as possible in reducing heat loss. British homes have focused on the two main factors which affect heat loss through the building fabric: thermal bridging and excessive air leakage through gaps in the construction.[1] Thermal bridging occurs when there is a break in the thermal insulation. This is more probable in Korean high-rise apartments, because most of them have insulation in the cavity wall or inner part of the wall. This break provides a path for a rapid loss of heat from the inside to the outside of the dwelling. The loss of heat can cool the structure to a point where the relative humidity close to the surface is sufficiently high to provide the environment necessary for mould growth. Under these conditions, finishes and decorations will gradually deteriorate. This is also a reason for condensation. The best way of avoiding thermal bridging is to maintain continuity of the insulation or overlap the insulation layers, and to use a material with good insulating properties. In the design, the gap between ceiling joint and gable wall should be covered with insulation.[2] Another option for avoiding thermal bridging is to install insulation materials outside walls, which hardly make a break in the thermal insulation. Some construction companies have recently adopted this method in building apartments, but it is still far from being a common trend.

7-1-2. Improving Mechanical Heating Systems for Energy Saving

An underground heating mode for apartments in Korea has been developed, following an agreement in the 1960s to provide housing with such a system. Although the underground mode has been maintained, a significant change from using heated gas directly through underfloor pipes, to using hot water pipes in a central heating mode, was a turning point in the history of heating in Korean residential buildings in the 1970s. Apartments built in those days had an individual boiler in each unit, which was easy to install and control. From the 1980s, as the size of estates and buildings has increased, new apartment buildings tended to have a central boiler to cover all apartment units in a building or even in a whole estate, eliminating the use of small boilers in each apartment unit. Although this central heating system has inconveniences because of lack of private control, it has greatly reduced the amount of energy consumption and pollution production.

The adaptation of the district heating mode in the 1990s was another important point in the development of apartment heating systems. This mode has led to a further reduction of energy consumption for heating and hot water in Korean high-rise apartment buildings. The systems have been installed in Seoul and some new towns, where massive amounts of heat, hot water and electricity are required, and will eventually be extended to medium and small sized cities throughout the country. Since most electricity is produced in power plants, use of the district heating mode, which adopts CHP (combined heat and power), is especially efficient. The district heating system can also be used in combination with underfloor heating, the Korean traditional heating mode, because both of them use a hot water circulation system.

Although the underground heating mode can provide thermal comfort in relatively lower room temperatures, the price and embodied energy for initial installation is very high. Pipes made of copper, which is the most efficient material for heating distribution for underground heating, need enormous energy during the manufacturing process. The embodied energy for copper pipes exceeds that of most other materials. It is very important to recycle these copper pipes, although it is not easy to separate them from main structures, which are usually concrete slabs. Modern technology for producing vinyl pipes has a great impact on the reduction of embodied energy, while these pipes have the same or even better thermal performance as copper pipes. The use of vinyl pipes for underfloor heating in Korea is now at a trial stage, and has great potential to reduce environmental impacts in the future.

It is difficult to replace the underfloor heating mode with other modes in Korean dwelling buildings. Attempts at replacement were made in the late 1980s, for instance, installing radiators in apartments in the Olympic Village in Seoul. They gained public attention at first, but the dramatic fall in the market price of these apartments, in spite of their good location, indicates the alternatives are not viable for Korean apartments. It was found that some units, which had radiators, have replaced the mode to underfloor heating, requiring more financial and environmental costs. Therefore, in the Korean context, rather than disregarding the underfloor heating mode, it is preferable to develop improved-performance materials for underfloor heating pipes, with less embodied energy. Recent research and trials of vinyl pipes on construction sites indicate a brighter outlook for future development.

The district heating system is one of the most energy efficient heating installation types. Since it can be controlled by an individual thermostat installed in each unit, it is certainly an upgraded system compared to the central or individual heating mode. Residents can either save on their costs or increase room temperatures by easy control of their own thermostats. Through installing CHP (Combined Heat and Power), this system can also provide electricity for a certain district. However, the system itself also requires improvement. For example, careless design of meters for individual units has led to some complaints from residents. Hot water temperature running through the pipes is sometimes not adequately high for the whole town. More sophisticated boiler systems are required to accomplish the task. The district cooling system, which is now running in offices and hospitals within the towns where district heating systems are in use, could be extended to high-rise apartments, as the number of apartment units which have cooling devices has been increased recently.

7-1-3. Energy Saving through Building Materials

The importance of energy saving potential through choosing building materials carefully has not been well acknowledged in Korea. Issues regarding materials have concentrated on the safety of the structure and security of their production. The former issue emerged after suffering a series of collapses of buildings and infra-structures, and the latter following the excess demand for some building materials over the capacity of factories due to the massive increase in apartment building construction in the 1990s. Recently some materials have needed to be imported from other countries, resulting in the consumption of massive amounts of energy for transportation. It is, therefore, essential to extend material production facilities before increasing the number of buildings. The recent trend of constructing nearly triple the number of housing units per year compared to previous decades has certainly helped the accomplishment of the quantity target, but has left doubts regarding quality. They look luxurious in terms of the size of each unit and the design of each estate, but confidence is lacking as far as the safety of such buildings is concerned, due to the problem of material shortage.

The embodied energy of high-rise apartment buildings is generally great compared to other types of dwellings. Current regulations for insulation have increased the energy content for material production. Shortage of labour requires an automation system for construction sites, which needs further energy during construction. The attempt to calculate energy content for building materials and their use, however, has not even been recognised in Korea, even though energy intense high-rise apartments are one of the most widespread types of constructed residential buildings. The assessment in previous chapters will hopefully be a yardstick for future concern in this topic. Although it may not be accurate because of the method of calculation employed in British cases, there will not be huge differences in producing the same kind of materials.

The figure for initial embodied energy in Korean apartments is very high, marking 1571 KWH/m^2, while that of British high-rise apartments is less than 1000 KWH/m^2. The embodied energy of Korean apartments is equivalent to that of about twelve years' operation for the same buildings. If the initial embodied energy can be reduced to the same amount as in British cases, the amount of savings will be as much as that of nearly five years' operation of the same building. The value for British apartments is based on 1975 research, which means that the figure in recent apartments will be much higher because of, due to, consolidated regulations for insulation materials. Nevertheless, the value of embodied energy for Korean high-rise apartments is very high, and this is the right time to consider embodied energy for building materials for sustainable future construction.

Although it is very difficult to define the best construction method for energy because of complicated manufacturing processes, energy saving from choosing better building materials could be achieved in the Korean construction industry, with the help of research from the United Kingdom. Choosing mineral fibre rather than polystyrene beads or polystyrene for insulation, for example, will significantly reduce energy use and carbon dioxide emission. The recent trend of replacing copper pipes with vinyl pipes for underfloor heating distribution systems will also reduce the energy content. Selection of floor finishes should also be considered, since there is a variety of materials that have been tried recently.

7-1-4. Policies for Energy Saving

Successful political efforts on economic growth in Korea in the second half of this century have eliminated people's food concerns. The enormous increase of industrial activity has given people wealth, but consequently, gradually degraded the regional and national environment. Recognition of environmental degradation in the 1960s and 1970s was ignored, the priority being economic growth. However, since the 1980s, efforts to improve the regional and national environment have improved the environment in statistical terms. The target should now be a global environment for the survival of all human beings. Energy conservation, especially that from burning fossil fuels, is one of the solutions for saving the globe, both from the resource and pollution perspectives.

Increase of energy use in Korea has been noticeable since the 1960s, when economic growth was the major priority in governmental policies. Energy use in 1994 was more than six times as much as that in 1970, as shown in Chapter 2. A lesson learnt from those days is that there was a certain period of a little increase or even decrease of energy use in the late 1970s and early 1980s, whilst there was constant economic growth in the same period. This was because of world energy fluctuations, which implemented an enormous increase of oil prices. From the late 1980s, however, the trend of dramatic increase in energy use started again, when oil price became stabilised. Although there is continuous promotion of energy conservation and efficiency, such as the expansion of district heating systems and adoption of energy impact statements, the trends of massive increase energy use is still going on in the mid 1990s.

Regulations for energy saving in the construction industry in Korea have focused on the use of efficient heating instalment and the thickness of insulation for buildings, which certainly have been effective in reducing energy consumption during the building operation. Regulations requiring a certain amount of sunshine to enter into houses or apartments, originally intended for mental health or keeping with tradition, have also helped reduce energy consumption, by using passive solar energy. Current political targets for energy saving in the construction industry should be included in the process of construction, which covers the selection of materials and their use. Like the numerical regulations for the thickness of insulation, establishment of regulations for embodied energy in the process of apartment construction is recommended for reducing energy consumption. Apart from the establishment of regulations, general guidance from national or regional governments to the residents of apartments will help conserve energy in the operation of buildings.

7-2. Lifecycle Planning of High-Rise Apartments

The appearance of high-rise apartments can only be traced back to 25 years ago. Since then, this form has become the dominant one for housing construction in Korea. Recent development of new towns around Seoul has a significant role to play in the upward trend in the number of high-rise apartments. In Pundang New Town, for example, around 80 per cent of housing is apartment buildings, most of them high-rise. Paralleled with apartment construction in new town developments, high-rise apartments have replaced low-rise apartments and old houses in city centres. Recent redevelopment of low-rise apartment estates tends to limit the life of those buildings to only around 20 years. This has an enormous effect on the environment by demanding massive amounts of building materials and energy, and by producing waste. If the replacement of low-rise apartments extends to high-rise apartments, a more serious impact on the environment will be felt. Proper management and maintenance systems are required in order to extend the life of these buildings.

7-2-1. Design with Life-cycle Cost

When an apartment building starts its life-span, its projected life-span may affect the design of a building. Materials may be different according to whether the building will last longer or not. Consideration of repair plans also differs according to the life-span. Buildings designed to have a longer life-span usually require more initial costs and energy. However, if some are concerned about the cost of the building, the initial money will be recovered through savings made during the maintenance process. However, it is not easy to implement the life-cycle design because the life of a building does not always match its physical conditions, but, in some cases, it can be defined by social, economic and political conditions.

Construction companies in Korea have set targets for recent apartment buildings according to the number of units and their initial selling. Priorities are given to location, decoration and convenience of apartments, rather than the life-span or maintenance.

Since the land price is very high in big cities, one of the most important factors is how many units can be built on a certain estate. Design strategies for easy-repair plans are hardly to be found in construction companies, as they concentrate on the initial condition of apartments. Unlike Hong Kong and Singapore, where the same company has the responsibility for construction and management, both responsibilities are implemented by independent companies in Korea, although the responsibility of management is undertaken by the construction company for one year as a compulsory period. Although construction companies have responsibilities for the conditions of certain components of apartment buildings, this is far beyond their priorities when they construct apartment buildings. They try to improve the initial condition of apartments, which is vital for selling, but do not seem too concerned about the life of the building thereafter. The priority for construction companies now needs to shift to taking care of their own products in the long term.

Embodied energy for the whole building life-cycle emerges as another issue in the United Kingdom, as shown in Chapter 6. The David Langdon Consultancy has produced a sequence of research results for embodied energy building materials for the life-cycle assessment.[3] Initial embodied energy, including all the energy used to acquire and transport the raw materials, manufacture of these into construction materials or components, transport of them to construction sites and building into structures, is calculated and the energy required for maintenance and refurbishment are added later. Since embodied energy for maintenance and repair for about 60 years is usually less than initial embodied energy, sometimes just around half, extension of building life will help to reduce a certain amount of energy and material use. If the energy for demolition is included, further energy savings will be acquired. As a starting point, at least, construction companies need to think about the importance of the life-span of apartment buildings.

7-2-2. The Management and Maintenance Systems of High-rise Apartment Estates

Although it is important to think about the life of a building at the design stage, the condition and life of the building can be improved through a proper management and maintenance programme. Regular repair of small faults may avoid a serious defect later, and can sustain a building. The proper condition of apartment buildings can also affect social recognition, which is another factor in the life of buildings.

Apartment buildings are usually built by private companies and sold to residents in Korea. Since the residents have ownership, they have a responsibility to upkeep their units, as well as public spaces within the estate. The establishment of management offices, which are in charge of the management and maintenance of apartment estates, have helped residents to improve the condition of apartment buildings. However, it is difficult to draw a single conclusion where many different people have different opinions about an apartment building or estate. Financial problems are always a barrier to implementing plans.

Management offices in apartment estates in Korea have developed along with the increase in the quantity of apartment buildings. They first appeared to improve the harmony of neighbourhoods, cleaning public spaces or providing security against vandalism within estates. Their duties have extended to the general management of apartment estates and maintenance programmes including long-term repair plans. Along with the expansion of an estate size, duties and responsibilities for management offices have increased. The duty of management offices has become more specialised, requiring many specialists such as mechanics and electricians.

Life extension for apartment buildings with long-term repair plans is strongly approved by management offices. Even though there is not much concern in the construction stage, buildings may extend their life through well-established management. Since the first step, which is the establishment of management offices, has already been made, further steps for setting up proper maintenance programmes are now due.

7-2-3. Social Recognition of Long-life Buildings

Enormous economic growth in Korea has meant Korean people tend to give less priority to saving money when purchasing goods. The eagerness to seek modern and luxury dwellings has made a building's life even shorter, because most people, if not all, want to have new apartment units which are well-equipped for modern life, such as with a home automation system. This requirement is in accord with construction companies who seek in-site redevelopment where no big land blocks are found around those old apartment estates. In economic terms, nobody will make a loss through these redevelopments, thanks to the exclusively high land price. By increasing the plot ratio in an estate, construction companies, as well as the residents, can make a certain amount of profit.

The reconstruction of old apartment buildings, however, has a great impact on the global environment by using massive amounts of energy and materials for construction and producing waste. Although it is important to make a certain amount of profit in financial terms, the recompense to the environment for its economical benefit may not be recovered. Present populations, who can easily have access to energy and raw materials, need to consider preserving them for future generations. Where structural conditions are not serious, refurbishment and regular maintenance programmes should be adopted, which sustain both the building itself and the environment.

Summary of the Chapter

Through the assessment of Korean apartment development and through comparison with those in other countries, future development for sustainable environment is suggested in two broad categories - energy-saving strategies and life-cycle planning.

In terms of energy saving strategies, three methods has been categorised; (1) passive heating strategies, (2) improving mechanical heating systems and (3) reducing embodied energy of building materials.

In terms of passive heating, observing the tradition of facing south has helped reducing heating load. To maximise the merit of the orientation, balcony areas have been developed which may subsequently be converted to a greenhouse or thermal buffer zone, which can keep heat in during the winter. The argument here is that the instalment of windows for this purpose should be done during the construction process. A more stringent K-value (U-value) has also been suggested in order to maximise heat preservation, with careful design of thermal bridging and air leakage through gaps.

The introduction of the district heating system with CHP (combined heat and power) leads to energy savings without reducing thermal comfort. Improvement of the operating system through more careful design of meters, regulated water temperature and more sophisticated boiler systems are the tasks faced now. The extension of the system to district cooling will lead to further energy saving.

Whilst careful consideration of building orientation and unit plan for passive solar design and efficient heating systems for reducing thermal operation are well established, the importance of embodied energy of building materials both for initial construction and during the maintenance procedure is not yet recognised. The value of initial embodied energy in Korean apartments is much higher than in the United Kingdom. Taking the embodied energy into account for future construction is strongly recommended in order to minimise environmental impact from the building industry.

Apart from these methods, the importance of policies for energy saving has also been emphasised. Although regulations for energy saving in the construction industry in Korea have focused on thickness of insulation, more stringent standards are required for thermal performance. Establishment of regulations for embodied energy is also recommended. Regulations demanding a certain amount of sunshine in the living area, on the other hand, have helped reduce energy consumption.

The life of Korean apartment buildings is very short at present. Efforts for reducing energy consumption during building operations may not be very useful if the life-span is too short. An enormous proportion of initial energy input is necessary for construction because of its short life, and this needs to be considered properly. It is important that the importance of the longer-life building not only recognised for economical reasons but also for environmental ones. In order to achieve a longer life building, research into (1) design with life-cycle cost and (2) management and maintenance, as well as (3) social implications, is needed.

Shorter life buildings cost more not only in economic terms but also environmental terms. Use of energy and raw materials, as well as waste production, is inevitable during the construction and demolition process. The amount of energy used for construction is equivalent to that required for many years' building operation.

The life of buildings is influenced by the initial design and construction, but the life can also be extended by proper management and maintenance. Through employing proper long-term maintenance programmes by management offices, buildings may extend their life.

Social recognition of longer-life buildings is very important, since redevelopment has been done in some apartment estates where there is no structural defect. People should recognise the great impact on the global environment which comes from the reconstruction of old apartment buildings.

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Conclusion

1. Summary of the Thesis

Chapter 1 of the thesis, as the opening chapter, researches the global environmental issues in recent years. Awareness of the critical situation of the global environment has raised efforts to protect it on the international level. Dramatic changes in the global environment have created rapid agreements at international treaties and conferences concerning the world environment. Scientists have cooperated with politicians by exchanging their ideas with each other. Current efforts to transfer these ideas to practitioners give motivation to have helped implement them in the actual societies. Architects, as well as town planners and politicians, have become increasingly aware of the startling changes affecting our environment and how buildings play a role in these processes. In cooperation with professionals from various fields, whose aim is to save the environment, efforts in the construction industry have been made in the last two decades. Although the problems are on a global level, people have recognised that the solutions should be local. Through the accumulation of solutions from local bases, the world may be able to sustain itself in the future.

In this context, the current environmental state in a country, Korea, has been investigated in Chapter 2. The Korean government, which once focused on economic growth in its main policies, has shifted its priority towards solving environmental problems, both because of people's eagerness to live in a sound environment and the pressure of international environmental regulations. Efforts to make development and the environment more harmonious, have improved regional and national environmental conditions recently, although many people still complain about the quality of their regional environment, especially in big cities. Continuous efforts for the environmental improvement in urban areas will lead to a bright agenda for national environment. However, targets for global environmental issues, which require adequate use of energy and materials as well as protecting the ozone layer and treating waste, have not been well established, although there are quite a few issues raised by pressure groups. Future policy may include these issues, since the recognition of them will be increased.

In an effort to improve the current situation, all industries, acting together, need to be assessed properly, give effect to changes. Construction industry, one of which has great impact on the environmental, needs to be assessed from a local level, although the targets for sustainability are on the global scale. In order to help to establish targets for the global environment in the construction industry, high-rise apartments, which are the most popular construction type in Korea, have been chosen for deep investigation in this thesis. To understand high-rise apartments in Korea, the history and characteristics of high-rise apartments were described in Chapter 3. Massive construction trends in the 1990s force us to be concerned about future development. Considering the history and current trends of high-rise apartments, massive construction will continue well into the next century. Since the volume of high-rise apartment construction is very big, only a little improvement of each unit will add up to an enormous contribution to sustain the global environment as well as national and regional one. This leads to the need of establishing proper methods for environmental impact assessment.

As a strategy for minimising global environmental impacts of the building industry, an environmental impact assessment tool for high-rise apartments(EIAHA) has been developed through the references of current efforts mainly in the United Kingdom in Chapter 4. Through research from 'Building Research Establishment (BRE)', 'Building Services Research and Information Association (BSRIA)' and others, a method for high-rise apartments has been put forward. The EIAHA has four stages with each stage having two steps, that makes eight steps altogether. The EIAHA started from the design stage, where passive solar design can save energy for heating or cooling. The importance of insulation and ventilation has also been mentioned. In the next stage, the construction stage, the environmental impact of building materials was explained, concerning ecology, healthy and embodied energy. During the building operation, the need for energy continues until the end of the building life: thermal comfort requires the largest amount of energy. Heating systems and their operation, therefore, have been explained. Finally a life-cycle assessment has been pointed out, which lead us to stress the importance of proper management and maintenance system, which will help to extend the life of the buildings.

Through the establishment of assessment tools in Chapter 4, Korean apartment developments were valued in terms of environmental performance in Chapter 5. The assessments started from the early design stage, where passive solar design is considered. We have seen how this creates energy saving without incurring any extra environmental and economical costs. The tradition of solar design in Korean houses has been successfully transferred to current high-rise apartment developments, with additional new technology for insulation. During construction, the second stage, the choice of proper materials has been assessed. Although there is some awareness of the effect of building materials on the health, it is hardly to be found studies which take into account the embodied energy of building materials. The result of the embodied energy figure for high-rise apartment construction in Korea is, therefore, great enough to consider alternatives for future development. During the use of the building, the energy consumption for building operations is assessed, as well as heating installation. District heating systems, which contain CHP (combined heat and power), have contributed to energy saving and pollution reduction, although the energy use for building operation is still high. Finally, the importance of a building's life is pointed out, with suggestions for proper management and an effective maintenance programme. The life-span of Korean apartments is seriously short, so further efforts are required to extend a building's life. The result of the assessment shows a big discrepancy between steps. While Step 5 (heating mode) and Step 6 (operation of heating system) marked 'Good', Step 4 (materials' embodied energy) and Step 7 (building life) marked 'Bad'.

The results were compared with developments in other countries, the United Kingdom, Hong Kong and Singapore, in Chapter 6. Lessons have been taken from the failure of high-rise apartment development in the United Kingdom and from successful policies in Hong Kong and Singapore.

Targets for sustainable development for Korean high-rise apartments, then, were consolidated to energy-saving strategies and longer life design in Chapter 7. Items included social and political recognition for sustainable development, as well as some physical improvements. In terms of energy saving strategies, three methods has been researched; (1) Passive heating strategies, (2) improving mechanical heating systems and (3) reducing embodied energy of building materials, as well as (4) emphasising the importance of policies for energy saving. In order to achieve a longer life building, three items has been investigated; (1) design with life-cycle cost, (2) management and maintenance, and (3) social implications of building life.

2. Implications for Related People

Buildings are too complex for any single person or group to improve their status, especially apartments where many individual units combine together to make one building or one estate. As part of the construction industry, apartments require massive materials to be constructed, and use energy and produce waste and pollutants throughout their life. Efforts are required from a variety of people involved in apartment construction. Only the recognition of the environmental impact of apartment buildings may lead to an improvement in the situation, as well as an entire change in the way of living required. In order to develop environmental sound apartment construction, as part of the conclusion, implications of 'Planners', 'Architects'. 'Legislators', 'Management Officers' and 'Residents' are outlined.

Planners, as well as any other groups, need to recognise how the current trends of the construction industry can affect to the global environment. The materials and energy we consume for developing new buildings are finite, and the waste generated from the construction and demolition process is accumulated within the boundary of the globe. Development of new apartment estates will generate a greater traffic load, which will also require further energy consumption. Careful consideration of mixed development, avoiding unnecessary travel, is recommended, as well as well organised public traffic. Concentration should also be given to the extension of a building's life, since the life of current apartments is too short. Although it is difficult to say what the most appropriate life-span should be, a few more years of life extension will help to keep the environment sound. The technology for improving physical conditions is very important, but the actual life of a building is also related to social and economical situations. In order to extend the life-span, each building should be treated as a unique one, which can accommodate a variety of future residents. It is also recommendable to make efforts to improve the standards of existing buildings, rather than redeveloping them. It is worth considering changing the original unit, by making a bigger unit through combining adjacent small units or converting units from those for traditional families to those for single-person families.

Architects, or building designers, also have the potential to reduce environmental impact, in the design stage of a building. Understanding the seriousness of global environmental problems will be the first step to implement less-environment impact building design. Energy saving strategies are not only for technicians. Through adopting passive solar design, energy consumption can be reduced without additional building materials. When choosing building materials, architects need to understand the environmental impact of them in terms of ecological or health aspects and embodied energy. Efforts for creating new ideas for future generations will help to extend the life of buildings. These may include home-automation systems, units for elderly people or single-person families and may create community spaces.

The importance of legislators for the construction industry should never be under-estimated. Values of more consolidated restrictions such as K-value (or U-value) will reduce the energy consumption for a proper thermal performance. Establishment of restrictions for embodied energy of building materials will help planners and architects to take an environmental design into account. Legislation for redevelopment of old estates should be considered, in order to prevent the imprudent destruction of apartment buildings. Legislation for recycling used building materials will help conserve raw materials, saving energy and reducing waste.

Besides the initial design, buildings can be upkept longer, through proper maintenance and repair programmes. Management officers are not only important for maintaining the physical condition of apartment buildings, but also because they can improve people's attitude to their estates: residents' attachment to their homes may help to extend the life of their buildings. Setting a target of proposed building life is a first step for the officers, leading to the establishment of a long term repair plan. Understanding the physical life of each material will help to set a refurbishment plan. It is also recommendable to have mutual cooperation between architects or planners and management officers. Initial design which involves the idea of refurbishment can help to extend a building's life.

An important address for residents is to identify the current global environment issues and their responsibilities for them. Energy and material conservation and waste problems, are not only economical problems, but they are related to global sustainability. These issues threaten the survival of our own future generations, as well as ourselves and our neighbours. When simple actions for energy saving are added, the earth will maintain its health for a longer time. Recognition of the importance of a building's life is by the residents also important. Residents' reaction against the movement of redevelopment will help to extend a building's life.

3. Limitation of Current Research and Further Suggestions

This research attempts to post the importance of global environmental changes, and what Korean building industry should consider in order to minimise the environmental impact from high-rise apartment development. Although there is a lot of scientific evidence, predicting the future environment is not easy. Because the target, which is sustaining the globe for the future, is not clear, it is difficult to establish strategies for it. Within the current understanding, sustainability is set to conserve energy and materials while generating least possible waste.

While assessments are applied to Korean high-rise apartment buildings, the lack of information can not be overcome. Data of embodied energy values of building materials are taken from a British case, because no literature is to be found in Korea. The different manufacturing processes may result enormous discrepancies in values between the two countries. Therefore, the values mentioned in this thesis are only indicative, rather than absolute. The description of life-cycle of embodied energy for building materials does not go into depth, since there are no such examples which have a history of maintenance procedure throughout life-cycle because of the short history of high-rise apartments. British cases are also adopted here to figure out for rough guide. Some information, such as general environmental conditions and district heating modes, are described only in a very positive light, because main references come from governmental papers.

The information on Hong Kong and Singapore is also subjective, since it is mainly taken from governmental white papers. Accurate comparison for energy consumption could not be obtained for these two countries, since the climatic conditions in both countries are very different from that in Korea and the United Kingdom. Data taken from these countries, as well as those from the United Kingdom, are therefore only for establishing the recognition of the current problems of Korean developments, and proposals for their future development. Difficulties also arose in the assessment of British case, because almost all high-rise apartments in the United Kingdom were built in the 1960s and early 1970s, when different regulations were applied.

Through this small contribution, it is hoped that the importance of developing unique environmental design for each nation will be recognised. Because cultural, social, political and economical situations are different according to each country, strategies should be approached in different ways. Future research is proposed for sustainable construction industries in various countries, and the current thesis may be an example for fast-growing or developing countries. The assessment tool, EIAHA, should be transformed to different circumstances, if it is applied to other countries.

Future research into the Korean construction industry will hopefully consider the importance of environmental design in a holistic approach. It is desirable to perceive that fast changing global environment, and to adopt the ideas to the real construction industry. Along with these holistic perspectives, deep investigation of each issue - especially for the importance of embodied energy of building materials and life-cycle approach - is suggested. The proper transformation of assessment methodology from research in other countries to the Korean case will also be recommended.

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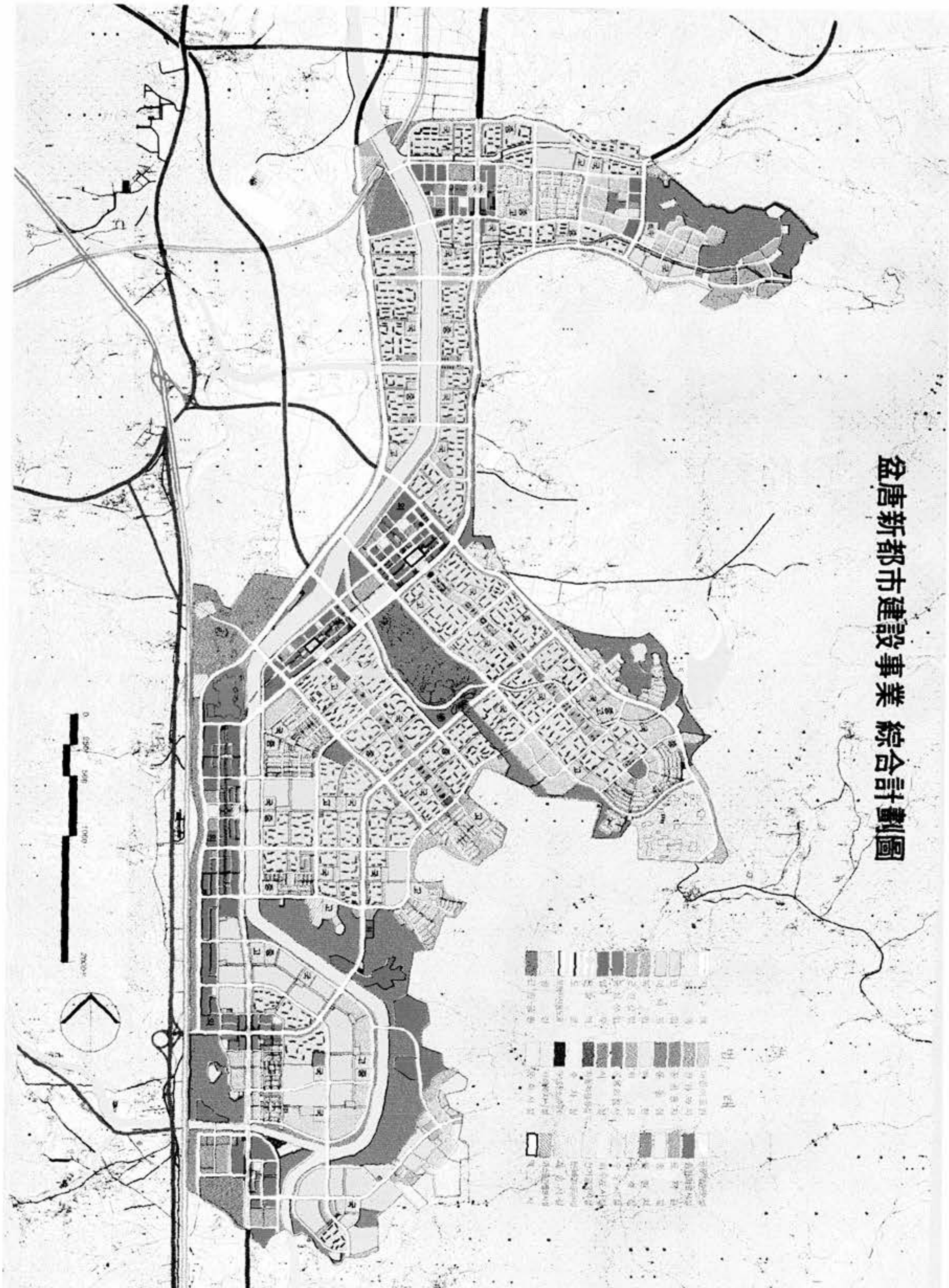
Appendix 1. Masterplan of Pundang New Town



Appendix 2. Number of Apartments in Pundang

NOTES

* Each Step and Block Name shown are presented in the map. They are named by Land Development Cooperation, which made the master plan of Pundang New Town.

* Name of Estate is usually the name of construction company for each estate. Some of them are different from construction company when the estates are not built by one construction company. Park Town (C19) is one of the examples.

* Number of block is the number of apartment buildings, and Hight is the range of apartment building storey, within the given estates.

* In the Number of Housing, A, B, C and D are devided in by the type or size of units. Apartment units catagorised in A are for rent, whilst those in B, C and D are for sale. Size of units in B is 25.7 PY (80 m^2) or less, that in C is between 25.7 PY (80 m^2) and 30.3 PY (100 m^2), and that in D is more than 30.3 PY (100 m^2).

* Occupied Date is the date when the units are ready for occupied. People can move in from that date. Numbers before the date is the height of buildings. Units in the same estate can be ready to move in on the different date according to the height of the buildings.

Step A

Block Name	Name of Estate	Number of block	Height	Number of Housing					Occupied Date
				A	B	C	D	Total	
A1-1	Samsung-Hansin	33	5-30		210	858	713	1781	5-16 : Sep.1991 17-30 : June 1992
A1-3	Hanyang	32	5-30	774	249	351	1045	2419	5-16 : Sep.1991 17-30 : June 1992
A3-1	Wooseong	29	5-30		220	1077	577	1874	5-16 : Sep.1991 17-30 : June 1992
A3-5	Hyundai	29	5-30		226	466	1003	1695	5-16 : Sep.1991 17-30 : June 1992
Total		123	5-30	774	905	2572	3338	7769	

Step B

Block Name	Name of Estate	Number of block	Height	Number of Housing					Occupied Date
				A	B	C	D	Total	
B2-2	Dongbu	21	12-17		364	582	188	1134	
B2-6	Korlon	18	13-16		188	768	126	1082	Feb. 1993
B3	Hyundai	25	14-20		424	1260	452	2136	14-15 : April 1993 16-20 : Dec. 1993
B4	KNHC				1747			1747	
B5	KNHC			851				851	
B6	KHNC			643				643	
B15-2	Daewoo	12	13-17				654	654	December 1992
B15-6	Sunkyeong	16	14-16		196	448	332	976	August 1992
B16	Kyeonghyang, etc	20	12-22				1166	1166	July 1993
B17	Kyeongnam, Byucksan	28	12-23		124	494	912	1530	May 1995
B18	KNHC	9	10-15	701				701	
B19	KNHC			1240				1240	
B20-3	Han-il	4	14-18		140	138		278	November 1995
B20-8	Hansin	5	9-15		132	132		264	December 1994
B20-13	Youngnam	4	12-17		162	132		294	September 1995
B22	Samhwan	10	10-25		40	168	364	572	10-17: Sep. 1994 17-25: March 1995
	Samsung	27	5-21		96	380	686	1162	April 1994
B23-2	Kunyoung	12	15-18				706	706	November 1992
	Taeyoung	8	14-17				414	414	November 1992
	Hanseong	8	5		50	190		240	November 1992
B23-6	Dongsan, Samho	24	5-22		80	240	812	1132	5-16 : Sep. 1992 17-22 : June 1993
B24-10	Punglim	16	10-22		80	176	620	876	10-15 : Aug. 1993 20-22 : April 1994
	Sunkyung	5	9-17		108	262		370	November 1993
B25-6	Dongsin	19	10-20		80	236	602	918	October 1992
B25-11	Jinheung	14	13-25		172	402	254	828	13-20 : March 1993 22-25 : Nov. 1993
B26-1-1	Sungji	4	12-18			168	136	304	October 1992
B26-1-2	Chonggu	13	13-25		130	232	348	710	13-18 : Aug. 1992 25 : March 1993
B26-6	Dongbu	2	15-20				132	132	12-17 : Feb. 1993 20 : June 1993
	Korlon	2	16-20				132	132	Feb. and June 1993
B26-8	Kumgang	7	15-23		120	378	90	588	15-16 : July 1992 18 : Nov. 1992 23 : July 1993
B26-11	Hansin								
B27-6	Hyoseong	7	9-25				388	388	9-10 : Dec. 1994 15-25 : June 1995
Total				3435	4433	6786	9514	24168	

Step C

Block Name	Name of Estate	Number of block	Height	Number of Housing					Occupied Date
				A	B	C	D	Total	
C6-2	Dong-A	15	5-19		60	192	396	648	5-16 : July 1992 18-19 : Dec. 1992
C6-5	Im-gwang	14	5-22		60	204	468	732	5-16 : July 1992 17-22 : April 1993
C6-19,21	Hyundai	14	10-22		60	186	464	710	10-16 : May 1992 17-22 : March 1993
C6-24	Samhwan	14	10-22		60	192	380	632	March 1993
C7-1	Daewoo, Daechang	11	10-25		302	600	0	902	August 1994
	Mirae	4	20-22			40	120	160	August 1994
C7-4	Rucky	5	10-22		80	228	0	308	August 1994
	Hwasung	5	10-25		208	356	0	564	August 1994
C8	Kunyoung	27	10-20		208	846	634	1688	10-15 : Dec. 1993 16-20 : Oct. 1994
C12-2	Life	9	13-25		112	490	194	796	13-15 : May 1992 16-26 : July 1993
C12-5	Dongsung	9	10-20		120	360	102	582	10-15 : May 1992 20 : March 1993
C12-8	Woobang	12	15-20		147	316	348	811	June 1994
C12-10	Samboo	14	5-25		130	358	100	588	5-16 : May 1992 25 : July 1993
C18-2	Hanyang	29	5-25	1010	176	180	640	2006	5-16 : April 1992 17-25 : Dec. 1992
C18-4,6	Kumho	24	12-26		158	246	1086	1490	12-16 : Apr. 1992 16-22 : Dec. 1992 22-26 : March 1993
C18-17	Chonggu	14	15-25		64	286	546	896	December 1992
C19	Park Town	41	13-30		172	494	2362	3028	13-24 : May 1993 30 : Feb. 1994
C20	Ssangyong, Sinsung and Byeocksan	50	5-22		360	912	1326	2598	5-16 : May 1992 17-22 : March 1993
Total		311		1010	2477	6486	9166	19139	

Step D

Block Name	Name of Estate	Number of block	Height	Number of Housing					Occupied Date
				A	B	C	D	Total	
D1-2	Han-il	7	14-23		112	136	168	416	14-17 : Oct. 1993 18-23 : June 1994
D1-6	Chonggu	14	14-25		232	392	234	858	August 1994
D1-9	Rucky	11	15-25				598	598	June 1995
D2-2	KNHC	10	10-20	1420				1420	10-15 : Aug. 1994 20 : Dec. 1994
D2-4	KNHC	17	10-15	1651				1651	
D2-14	KNHC	12	15-25		1039			1039	October 1995
D2-16	KNHC	12	15-25		1156			1156	

D3-1	KNHC				770			770	
D3-8	KNHC				1006			1006	
D3-7,11	Woosung	33	14-25		218	646	898	1762	Smaller : June 1994 Bigger : May 1995
D12-1,3	Life	13	9-25		72	212	466	750	9-17 : June 1994 18-25 : May 1995
D13-1,7,9	Hanil and Hanjin	20	9-25		146	452	594	1192	Dec. 1994 and July 1995
D13-5	Sinhwa	8	13-25		60	188	316	564	October 1995
D14-2	Woosung	6					270	270	May 1995
D14-4	Dong-A	7	14-23				300	300	April 1995
D14-12	Woosung	8	14-23		354	352		706	June 1994 and June 1995
D14-14	Dong-A	8	15-23		354	352		706	May 1995
Total		206(?)		3071	5519	2740	3844	15164	

Step E

Block Name	Name of Estate	Number of block	Height	Number of Housing					OccupiedDate
				A	B	C	D	Total	
E2-6	Boseong	4	13-18		70	214		284	May 1995
	Imkwang	4	13-18		70	214		284	May 1995
E4-5	Hanra	10	14-22		388	380		768	December 1995
E4-9	Yoochon and Hwain	8	14-25		176	448		624	November 1995
E5-5	KNHC	4(?)			474			474	
E5-9	KNHC	9	12-20	1250				1250	12-15 : Nov. 1994 20 : April 1995
E5-13	Dong-A	4	9-18				214	214	Feb.1995
E5-16	KNHC	6	15-20	1020				1020	15 : October 1995 20 : April 1996
E6-14	Daewon	14	13-25		60	164	596	820	- 15 : May 1994 16 - : June 1995
E6-20	Sungwon	9	12-25				454	454	December 1994
E7-8	Keryong	6	14-24		300	192		492	December 1996
	Seokwang, Youngnam	6	15-21		120	288		408	September 1995
E9-69	Sinwon	14	13-25		60	172	650	882	October 1995
E9-72	Lotte and Sunkyung	16	11-22		244	740	140	1124	July 1995
E10-6	Daewoo, Lotte and Sunkyung	16	9-25		222	662	92	976	November 1995
E10-14	KNHC	9	10-25		768			768	10: May 1995 20,25 : March 1996
E12-1	KNHC	7	10-21	779				779	10: Oct. 1995 21: April 1996
E13-45	KNHC	14	5-21	1489				1489	May 1995 & Oct. 1996
Total		160		4538	2952	3474	2146	13110	

Step F

Block Name	Name of Estate	Number of block	Height	Number of Housing					Occupied Date
				A	B	C	D	Total	
F1-1	Sinhan	6	15-20		140	342		482	April 1996
	Kumkwang	3	8-19		108	108		216	November 1995
F1-2	Lucky	14	15-25		150	422	316	888	September 1995
F1-6	Daerim	11	13-27		150	468	160	778	13-20 : July 1995 27 : June 1996
F2-1	KNHC	9	12-25		905			905	12-15 : July 1995 20-25 : March 1996
F2-3	Chonggu	13	12-18		360	572		932	May 1995
F2-11	Kunyoung	14	11-20		140	342	456	938	Sep. 1995, Feb. and April 1996
	Samsung	4	12-19				250	250	February 1996
F2-13	KNHC	5	15-25		563			563	15 : June 1995 25 : Nov. 1995
F3-6	Life	4	13-19				222	222	November 1995
F3-8	Dong-A	3	11-17				132	132	June 1995
F4-5	Je-il	3	12-18				172	172	July 1995
Total		89			2516	2254	1708	6478	

Total Number of Apartment Units and Buildings (blocks)

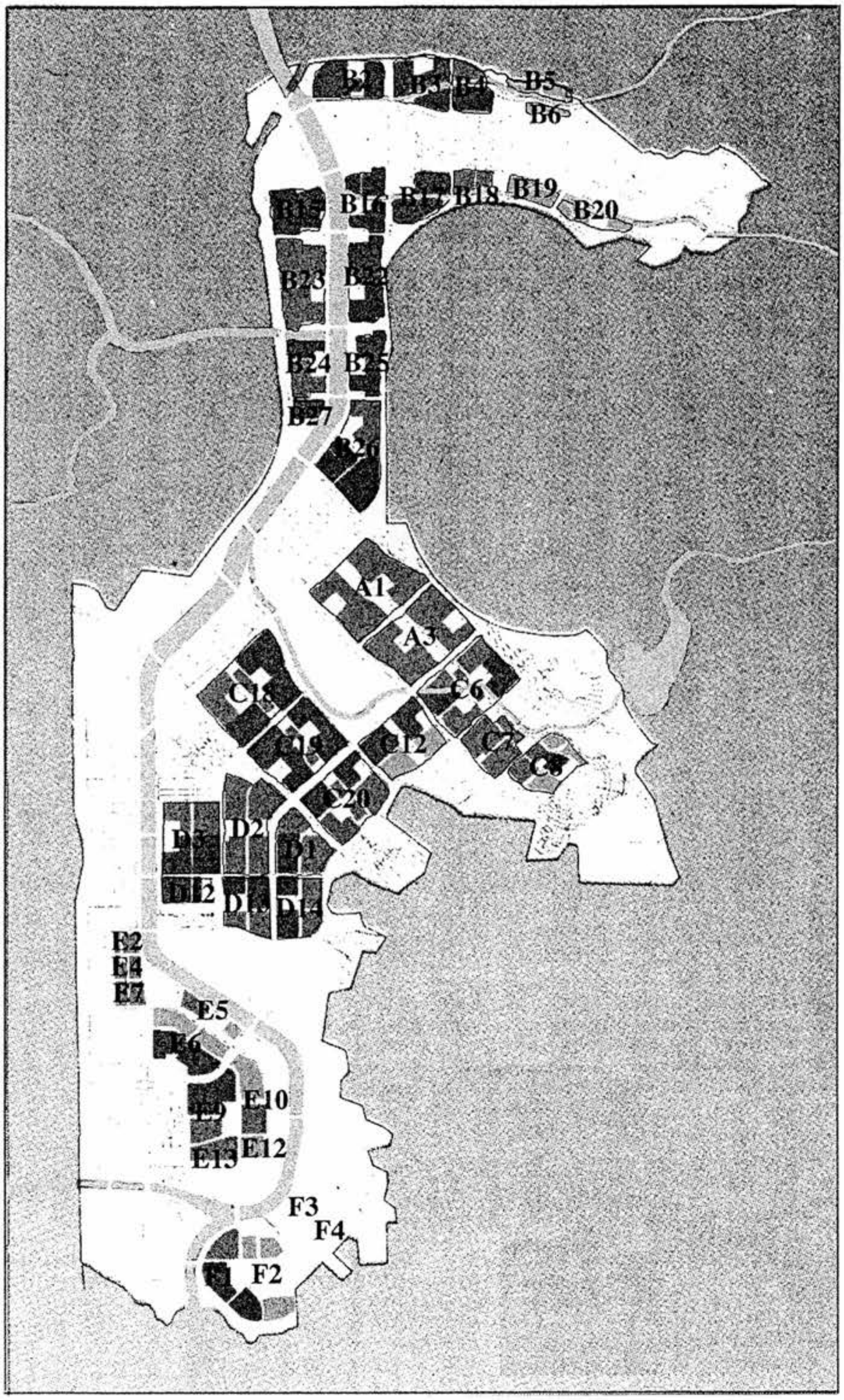
	A	B	C	D	Total	block
A Step	774	905	2572	3338	7769	123
B Step	3435	4433	6786	9514	24168	
C Step	1010	2477	6486	9166	19139	311
D Step	3071	5519	2740	3844	15164	206(?)
E Step	4538	2952	3474	2146	13110	160
F Step		2516	2254	1708	6478	89
Total	12828	18802	24302	29716	85648	1278(?)

Comparison of between Apartment Unit Number in Original Plan and Thouse of Actually Built

Type	Original plan	Units built
A	12,592	12,828
B	*42,891	18,802
C		24,302
D	28,482	29,716
Total	83,965	85,648

* B + C

Appendix 3. Location of Apartment Estates in Pundang



Appendix 4. Pictures of Apartments in Pundang


'95 6 14


510

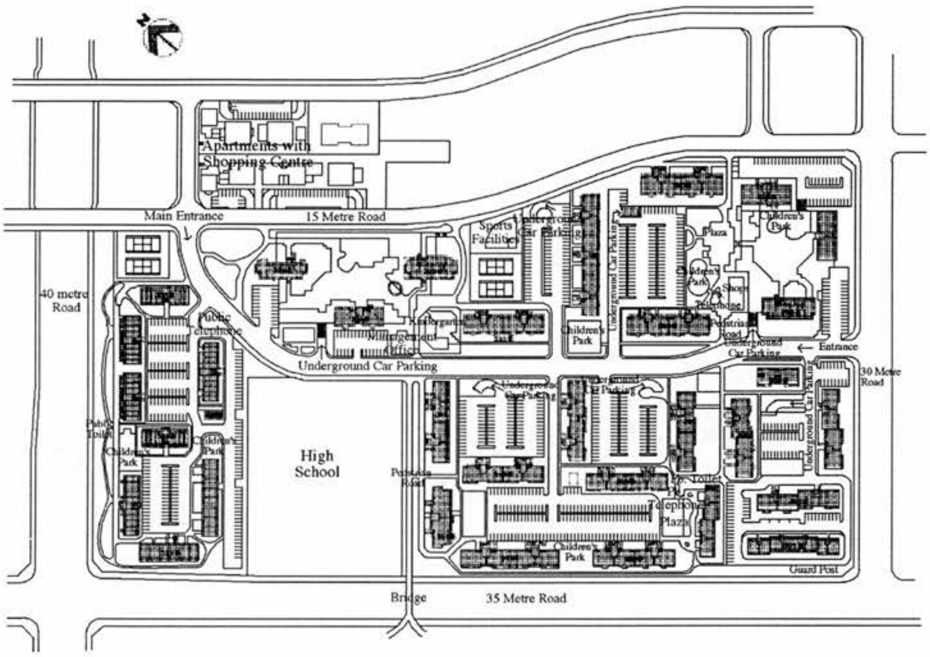

'95 6 14


'95 6 14

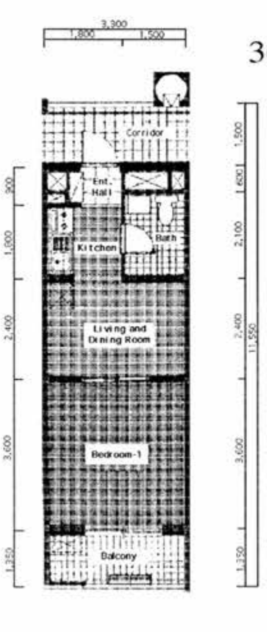
Appendix 5. Site-plan and Unit-plan of Five Apartment Estates

Pundang : HAN YANG APARTMENT

Site Plan

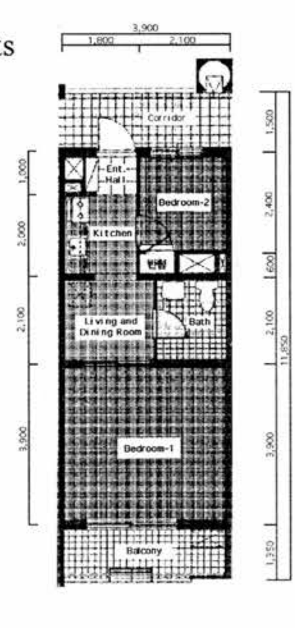


Unit Plan



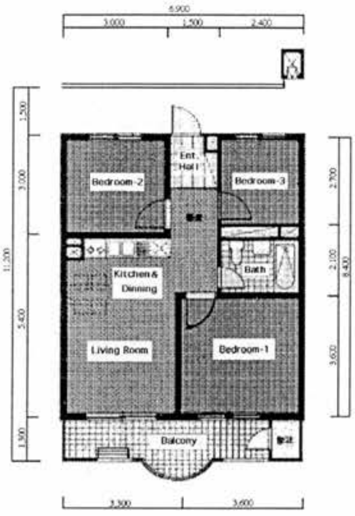
12
360 Units

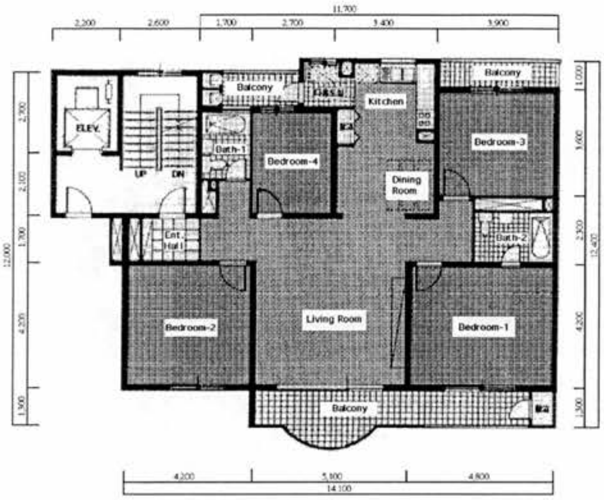
14
414 Units



Unit Plan - Han-Yang

24 209 Units



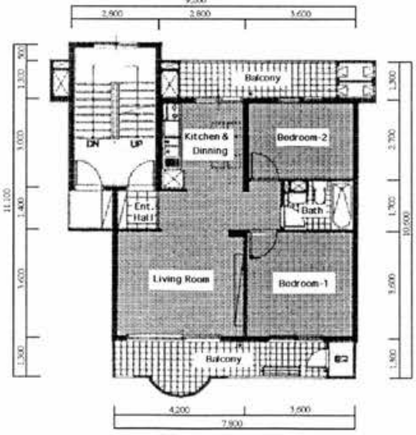


400 Units

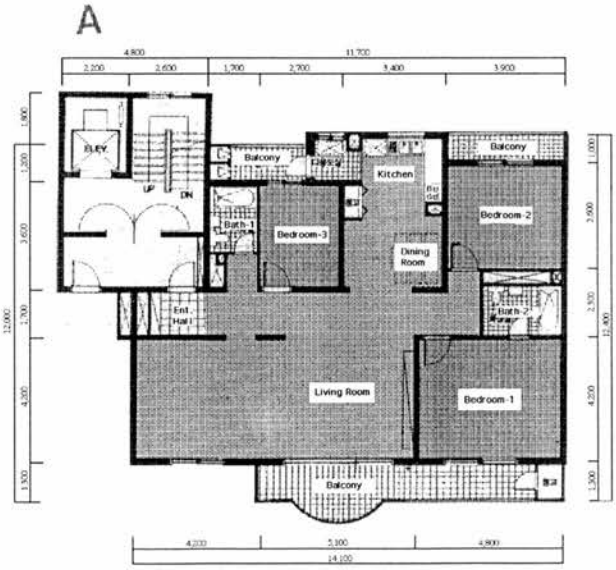
50

112 Units

22 40 Units



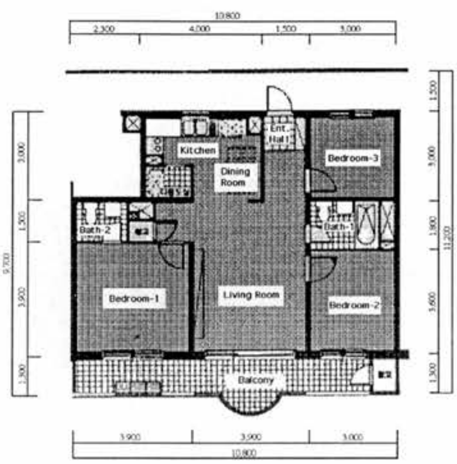
A



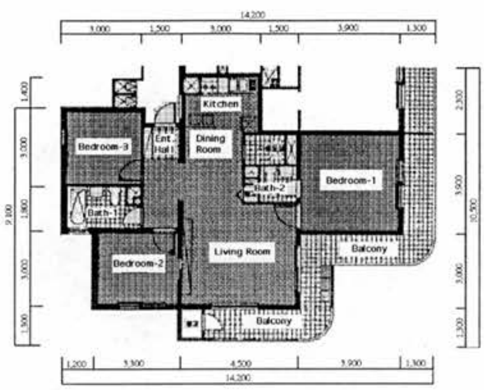
Unit Plan - Han-Yang

B 33 A

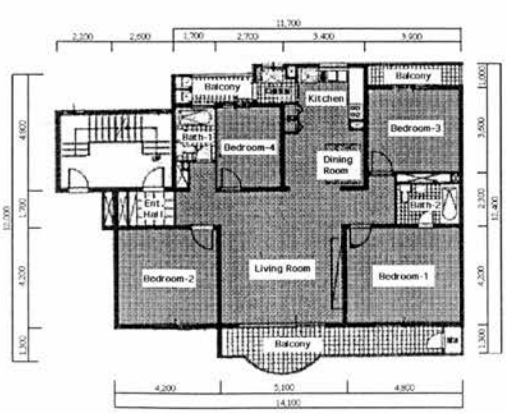
171 Units



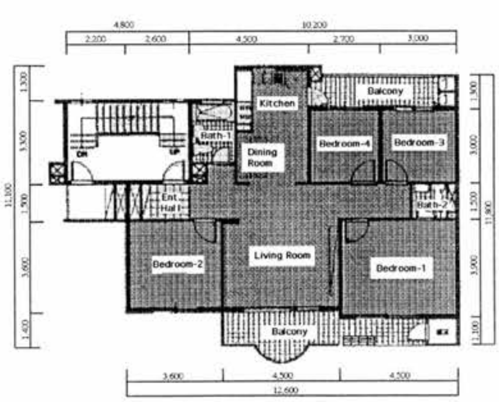
180 Units



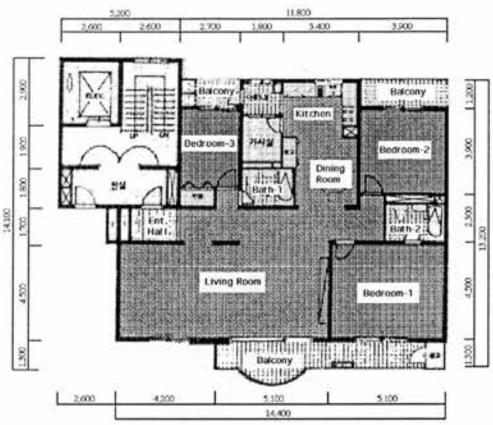
47 50 Units

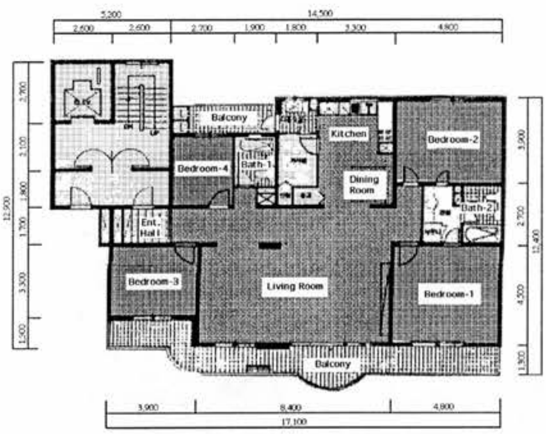


20 Units 36



Unit Plan - Han-Yang





A 41 Units

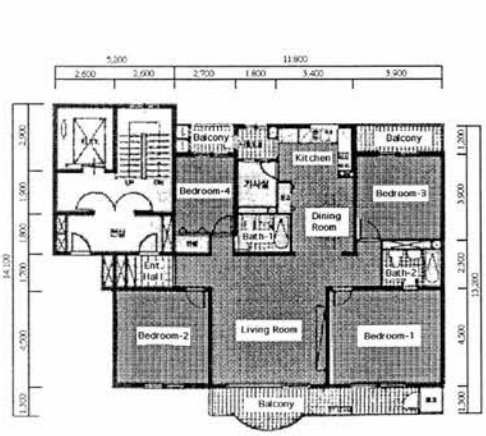
A 28 Units

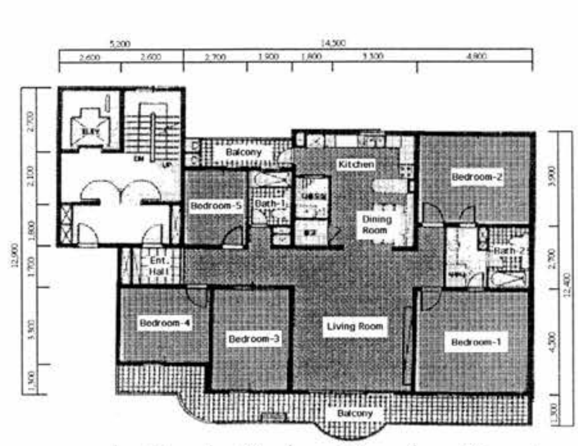
55

60

122 Units

205 Units

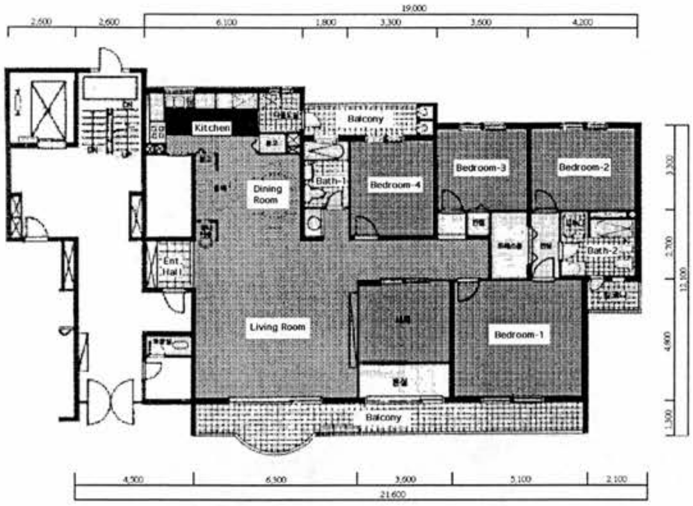




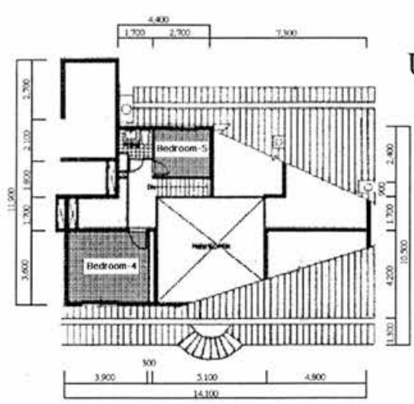
Unit Plan - Han-Yang

69

1 Unit



61

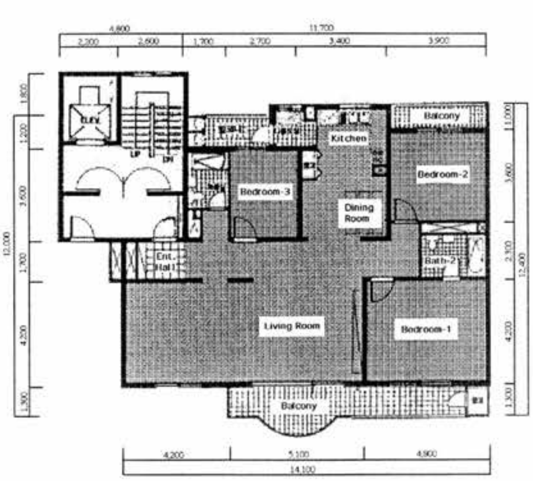


Up-floor

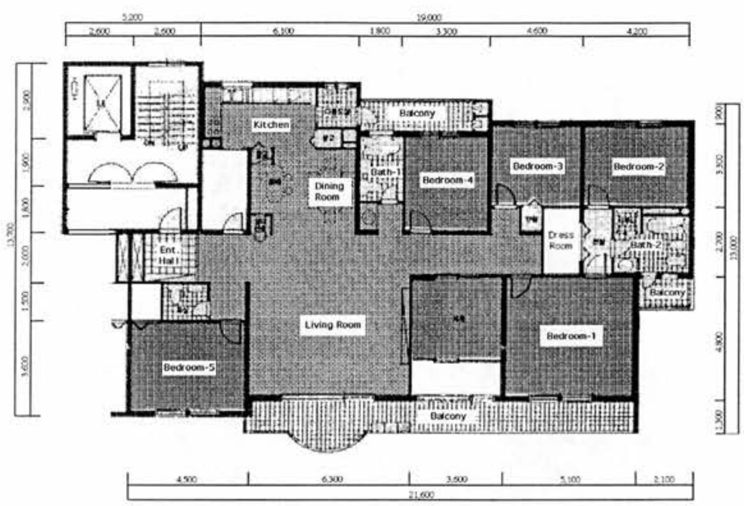
27 Units

A

8 Units

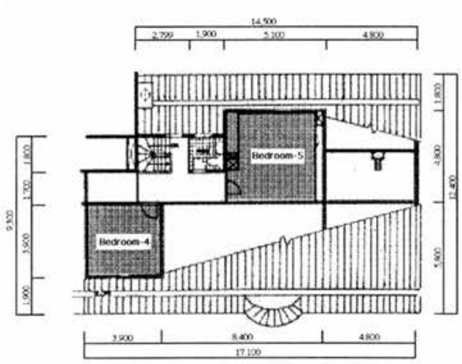


Unit Plan - Han-Yang

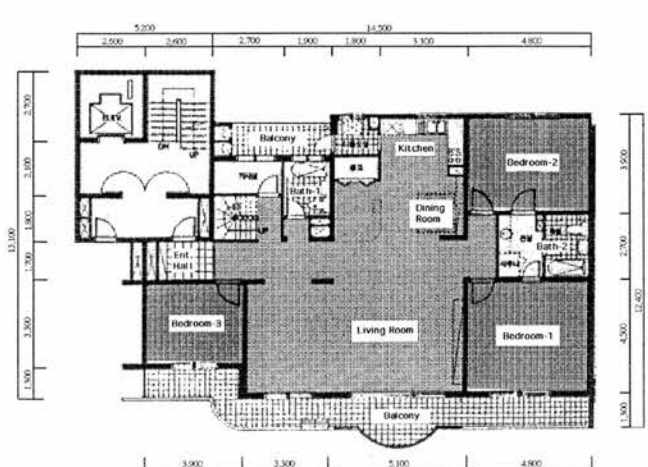


32 Units

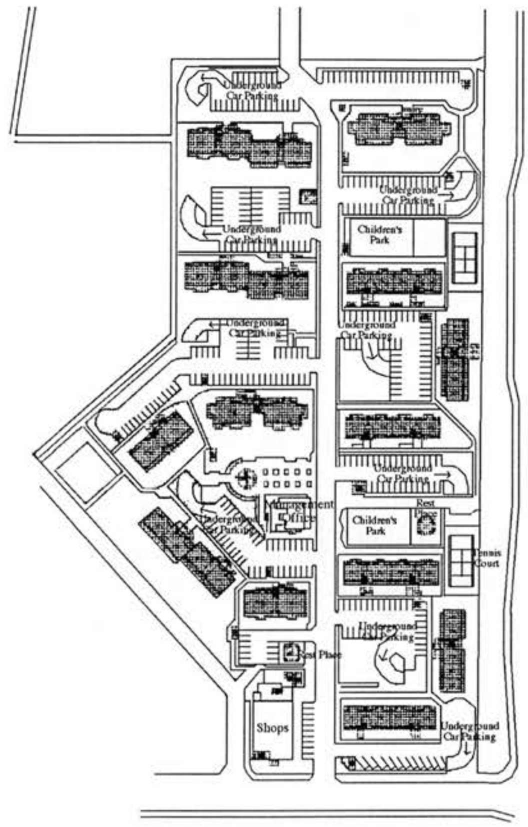
79



4 Units

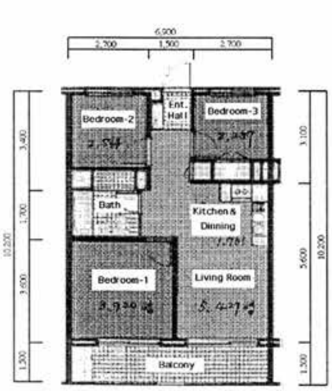


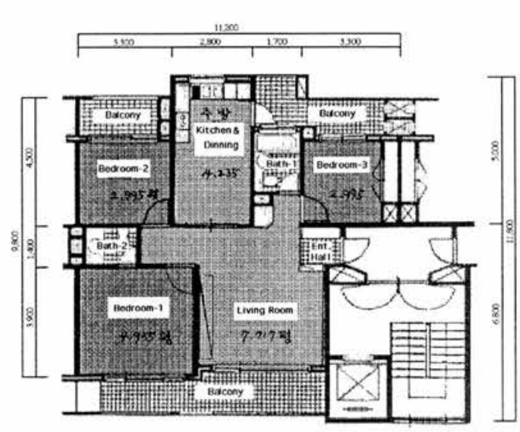
Site Plan



Unit Plan

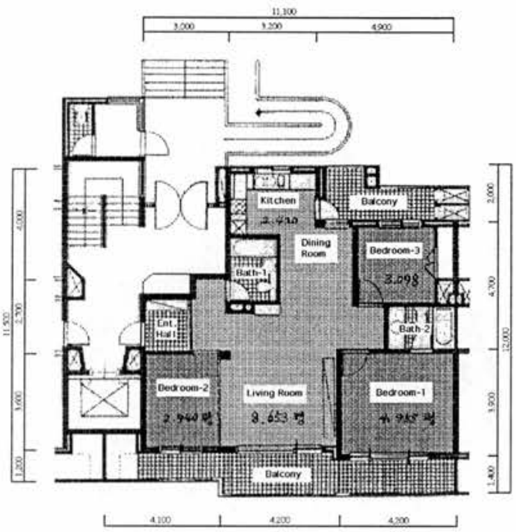
130 Units **24** **33** 232 Units



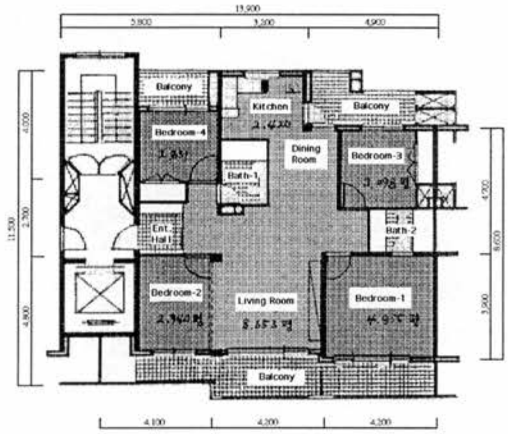


Unit Plan - Chong-Gu

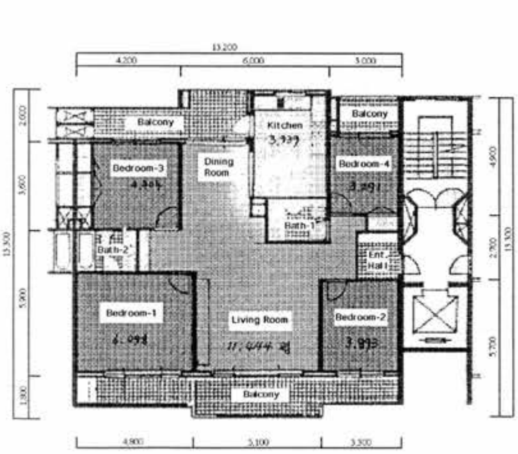
34 2 Units



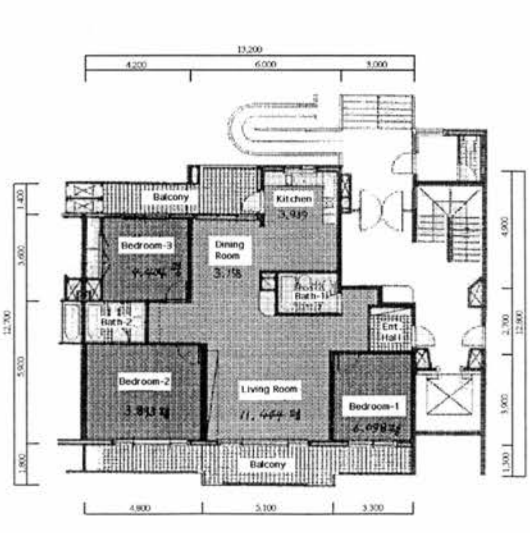
62 Units **38**



212 Units **49**

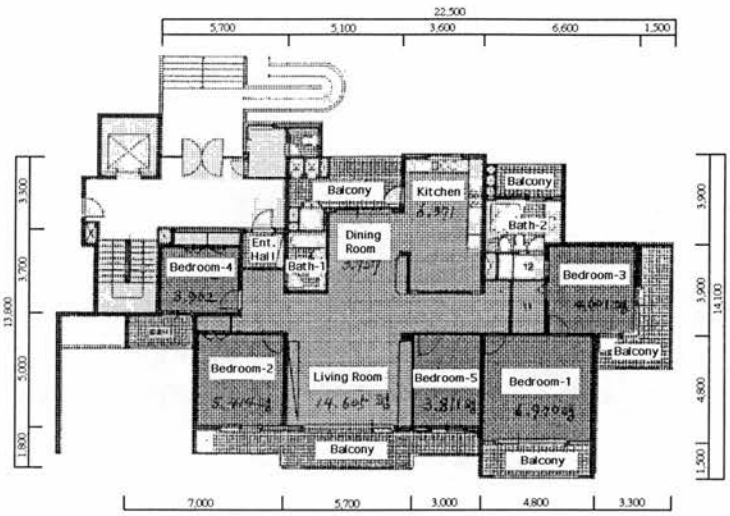


45 6 Units

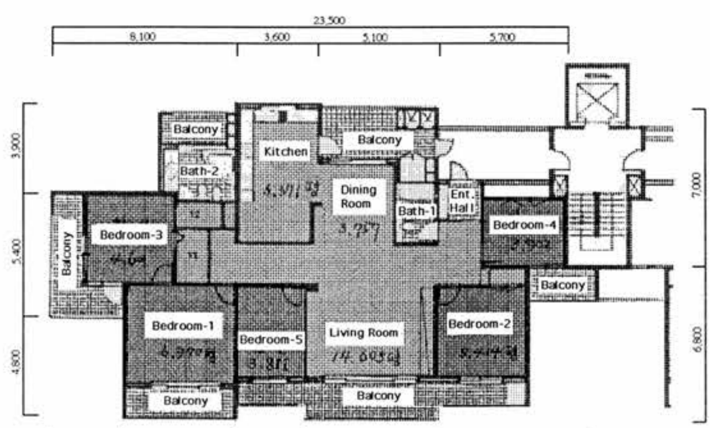


Unit Plan - Chong-Gu

67 2 Units

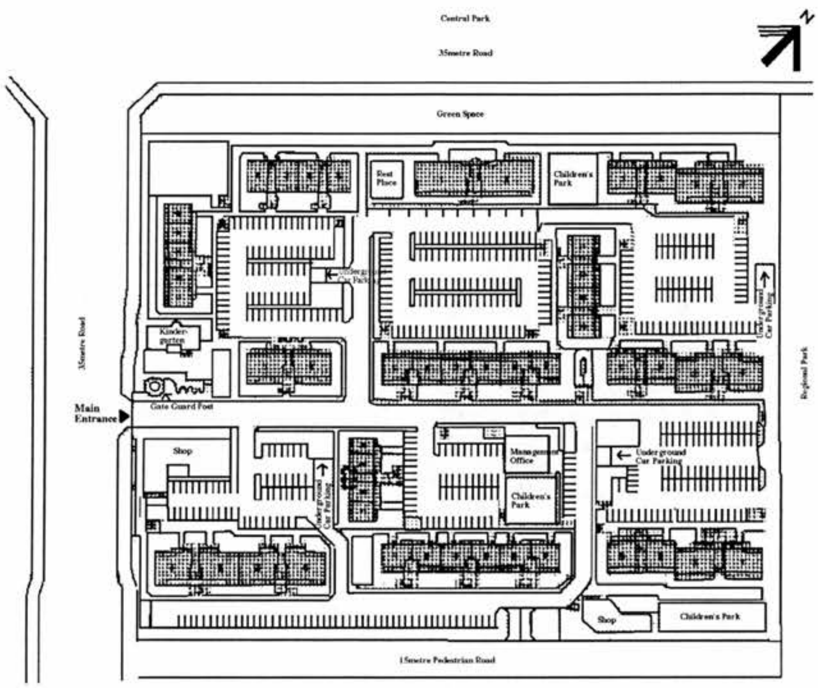


69 64 Units



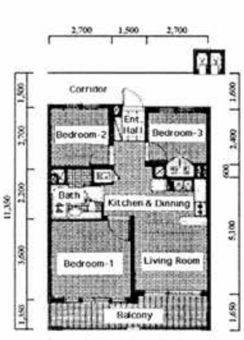
Pundang : WOOBANG APARTMENT

Site Plan

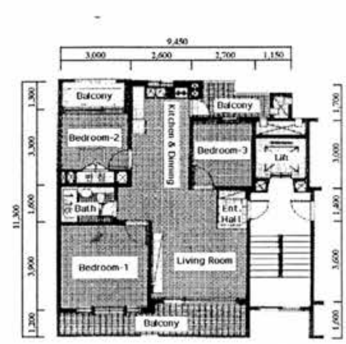


Unit Plan

23 147 Units

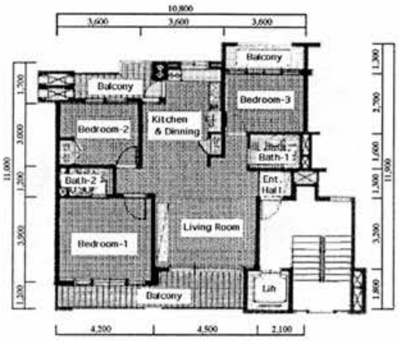


27 136 Units

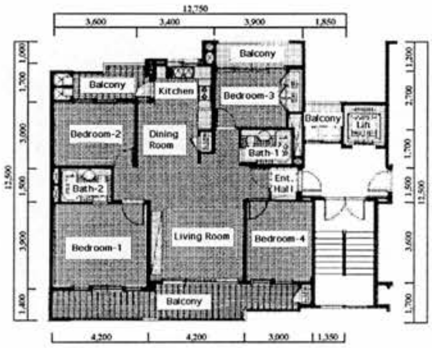


Unit Plan - Woo-Bang

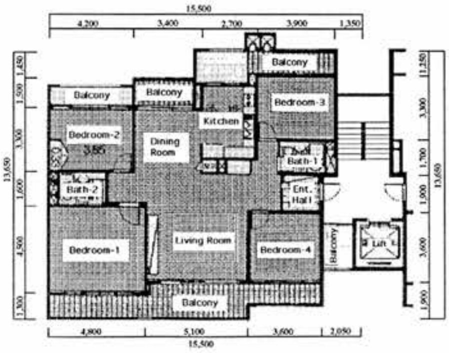
31 180 Units



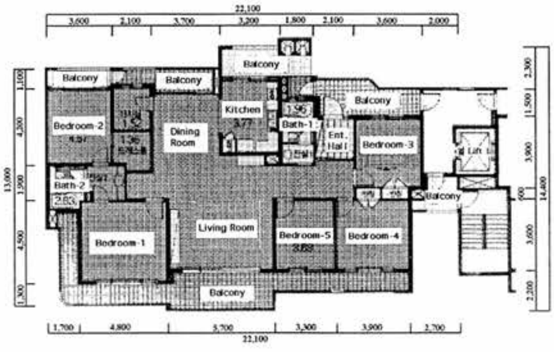
38 102 Units



48 210 Units

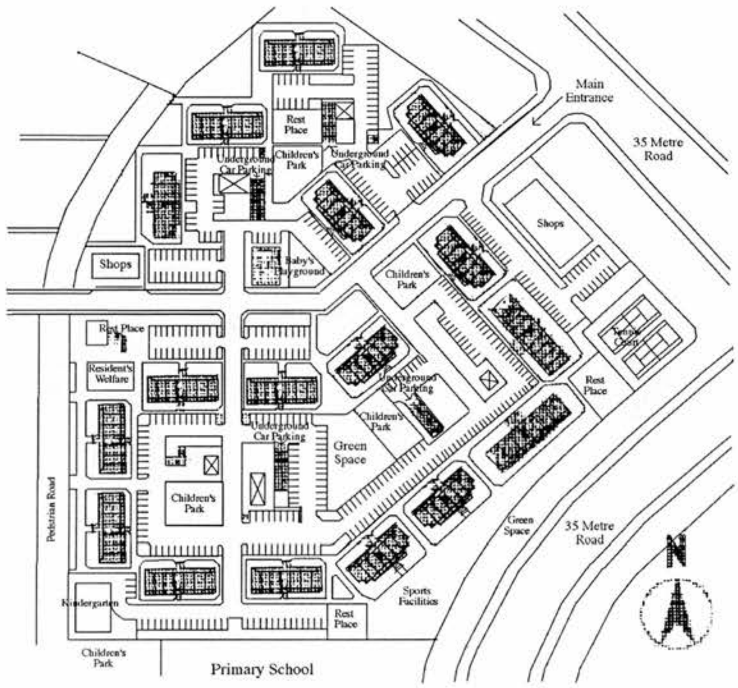


67 36 Units



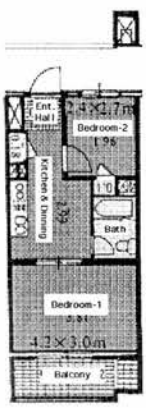
Pundang : KNHC - 1 APARTMENT

Site Plan

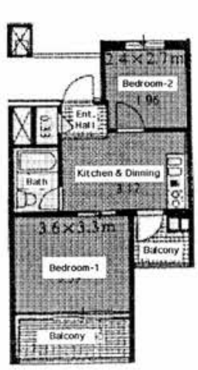


Unit Plan

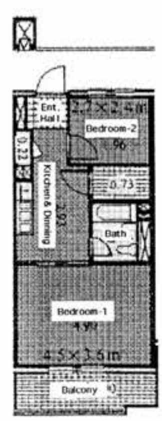
236 Units 15



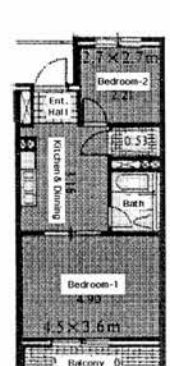
198 Units



534 Units 17

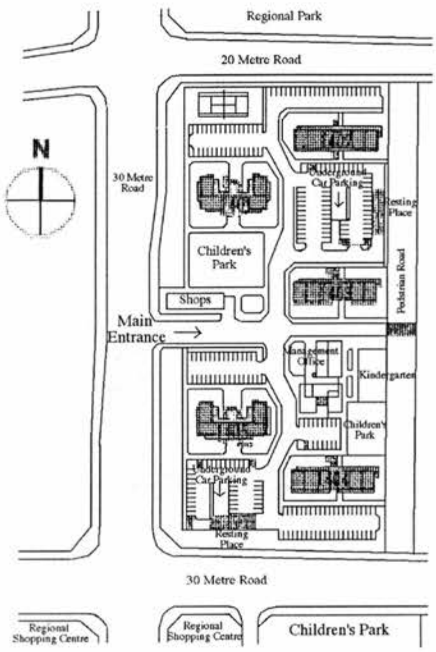


120 Units



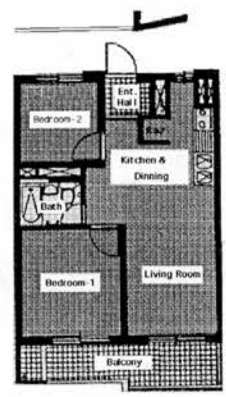
Pundang : KNHC - 2 APARTMENT

Site Plan

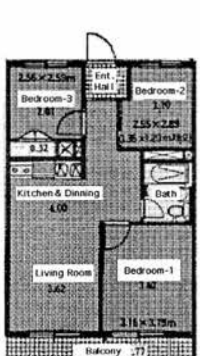


Unit Plan

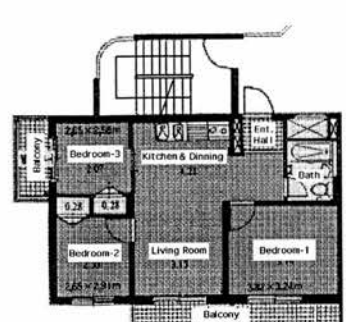
21 96 Units



24 267 Units



25 200 Units

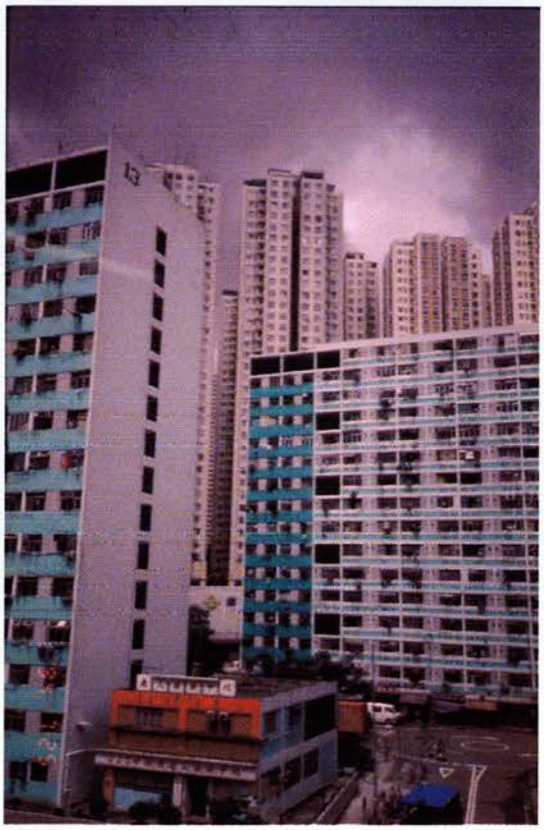


Appendix 6. Pictures of High-rise Apartments in the UK

Appendix 7. Pictures of High-rise Apartments in Hong Kong


'94 7 25


'94 7 24



Appendix 8. Pictures of High-rise Apartments in Simgapore


'94 8 6


'94 8 6


'94 8 6